DOCUMENT RESUME

ED 356 958 SE 053 193

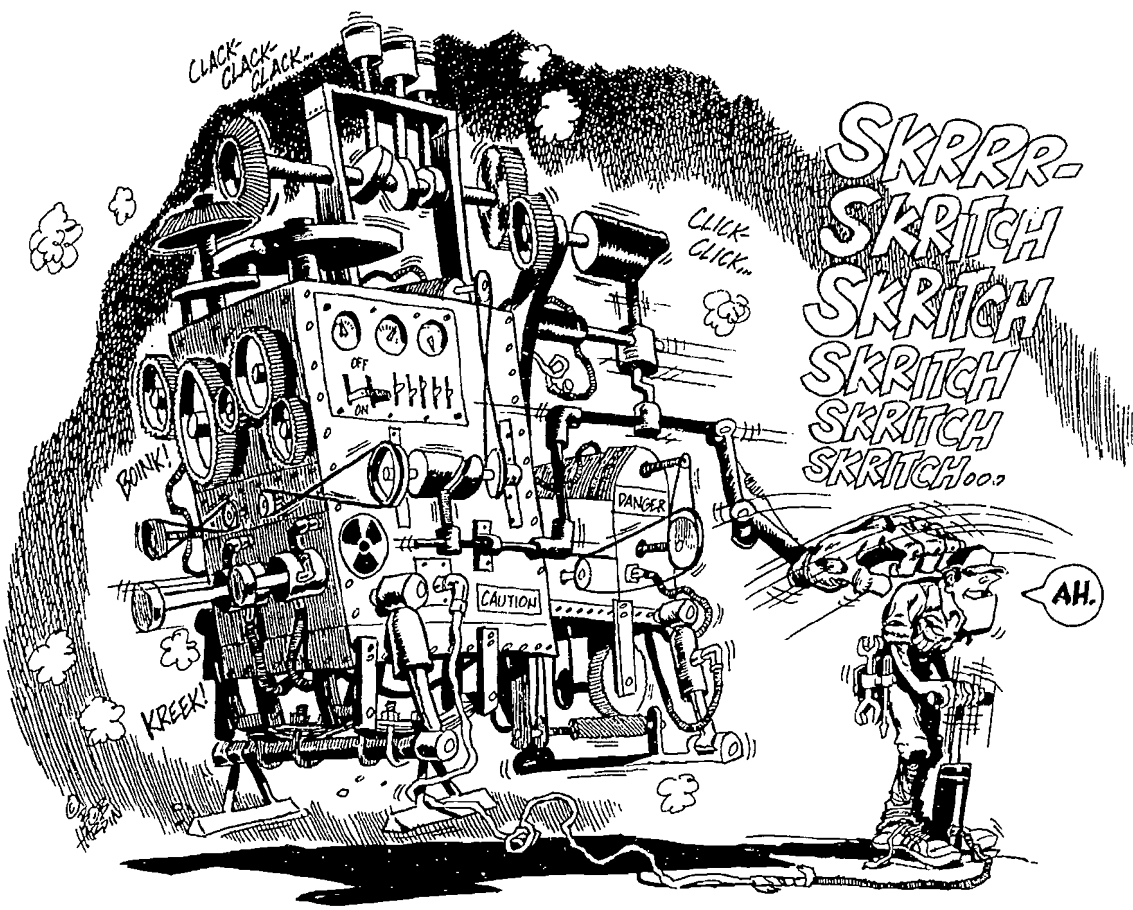
AUTHOR Collict, George
TITLE Basics of Control: The Mechanical, Hydraulic, and Pneumatic Transfer of Power and Motion. Project Description, Teacher's Manual, and Student Manual.
INSTITUTION Randolph Township Schools, NJ.
SPONS AGENCY New Jersey State Dept. of Education, Trenton. Div. of Vocational Education.
PUB DATE Feb 92
NOTE 64p.
AVAILABLE FROM George Collict, Randolph High School, Morris Count, New Jersey. (postage).
PUB TYPE Reports - Descriptive (141) -- Guides - Classroom Use - Teaching Guides (For Teacher) (052) -- Guides - Classroom Use - Instructional Materials (For Learner) (051)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Cooperative Learning; Curriculum Development; *Curriculum Evaluation; Design Requirements; High Schools; Hydraulics; Learning Activities; *Mechanics (Physics); Mechanics (Process); *Motion; Physics; *Problem Solving; *Science Activities; Science Curriculum; Science Education; Science Projects; Secondary School Science; *Technology; Vocational Education
IDENTIFIERS Pneumatics; *Technology Education

ABSTRACT

In 1990, the New Jersey Department of Education awarded the Randolph Township Board of Education a grant to evaluate the effectiveness of an existing technology learning activity called the "Magic Box", as part of the Teacher Developed Technology Education for the Nineties grant project. This document is comprised of three publications: a project description, a teacher's manual and a student manual. The project description describes the history and development of the program, research in support of the project activity, and the results of a professional program evaluation. Both manuals describe the project activity, which was designed to illustrate mechanical, hydraulic, and pneumatic transfer of control and addressed the following project objectives: (1) developing technological design and problem solving; (2) reinforcing basic concepts in science, mathematics, language arts, and other subjects; (3) developing basic skills in the proper use of tools, machines, materials, and processes; (4) solving problems involving the tools, machines, processes, products, and services of industry and technology; (5) developing fundamental concepts of how people create and control their environment; (6) developing a team approach to learning; and (7) identifying jobs and related education for technology related careers. The teacher's manual includes introductory activities for students; primary concepts and background information; lists of supplies, tools, and equipment needed; sample design briefs, principles of design, and specifications and limitations; and examples and illustrations. The student manual includes background information; a flowchart illustrating the problem; and sample design briefs and specifications and limitations. In addition, the teacher and student manuals both provide a project evaluation sheet, a list of related terms, suggestions for further research, and a page of drawings that illustrates each of the following: levers, lifting pulleys, revolving pulleys and sprockets, gears, and cams. (MDH)

BASICS OF CONTROL: THE MECHANICAL, HYDRAULIC, AND PNEUMATIC TRANSFER OF POWER AND MOTION



PROJECT DESCRIPTION

developed by:

George Collict
Randolph High School
Morris County, New Jersey

February, 1992

TABLE OF CONTENTS

This project was conducted pursuant to a contract from the New Jersey State Department of Education, Division of Vocational Education and was 100 percent state funded under the State Income Tax Revenue Account. Monies in this account are appropriated through New Jersey Statutes Annotated, Subtitle 7, State and Federal Aid to Schools, Section 18A:58-34 and 35. The contractors' undertaking of this project were encouraged to express their judgement in professional and technical matters. Points of view or opinions do not, therefore, necessarily represent official funding agency positions or policies.

STATE BOARD OF EDUCATION

INTRODUCTION

In the spring of 1990 a grant was awarded by the New Jersey Department of Education, Division of Vocational Education, to the Randolph Township Board of Education for the purpose of evaluating the effectiveness of an existing technology learning activity called the "Magic Box." This activity is part of a unit on control technology taught at the high school level within the Randolph Township school district.

The activity was first begun in the 1988-89 school year as part of an Introduction to Technology course which was implemented in the high school so both general and college bound students may better understand and adapt to the technological world that surrounds them. The elective course was patterned to address the fundamental goals of technology education that were established by the N.J. Commission on Technology Education.

IMPLEMENTATION MECHANICS

Grade level:	Grades 9 thru 12
Number of students enrolled:	1988-89 = 12 students 1989-90 = 24 students 1990-91 = 13 students 1991-92 = 52 students
Hours per week of instruction:	42 min. x 5 days/week = 3.5 hours
Weeks per school year:	Full year course = 38 weeks

STUDENT POPULATION

1. This is an elective course offering.
2. Students represent grades 9 thru 12.
3. Homogeneous grouping including National Honor Society students as well as mainstreamed classified and special needs students.
4. Boys = 90%
   Girls = 10%
5. College preparatory students = 80%
   Undecided = 20%
6. Interests, abilities and post-graduation plans vary widely.

ELEMENTS OF TECHNOLOGY EDUCATION ADDRESSED

1. Developing technological design and problem solving.
2. Reinforcing basic concepts in science, math, language arts, and other subjects.
3. Developing basic skills in the proper use of tools, machines, materials, and processes.
4. Solving problems involving the tools, machines, processes, products, and services of industry and technology.
5. Developing fundamental concepts of how people create and control their environment.
6. Developing a team approach to learning.
7. Identifying jobs and related education for technology related careers.

HISTORY AND DEVELOPMENT OF THE PROGRAM

In the early to mid 1980's, as a manufacturing instructor (machine shop and welding) in the high school's industrial arts program, I became more than passively interested in the role that computers and robotics were playing in both industrial arts and vocational education programs. While attending various workshops on these topics, I became aware of a change a few junior and senior high school industrial arts instructors were trying to make in their programs. In order to entice more students into their programs and to better address the impacts of rapidly changing technology, they were breaking from traditional project and skill oriented programs to instituting units of study focusing on learning skills and process oriented tasks.

Even prior to the release of the Report of the Commission on Technology Education and the subsequent Technology Education Curriculum Project, Level I, Introduction to Technology, an idea was proposed to implement a technology program in the high school. But where and how? The high school manufacturing program I was teaching was housed in a building several hundred yards away from the high school building, and we knew from experience the existing location would work against the success of installing a new program and would make it difficult to attract more students from the general school population.

With some schedule "jockeying" on the part of my supervisor, a space was made available in the back of the high school mechanical drawing room for a tabletop band saw and drill press. And that is where we "set up shop." My equipment consisted of those two machines, some basic hand tools, two computers, a few software programs, and some miscellaneous hardware and supplies.

The purpose of this background information is to take away the excuse that an exotic laboratory, sophisticated equipment, and large expenditures are necessary to implement a successful introductory technology program.

Even as students enter the "Principles of Technology" classroom at the beginning of the school year, they are made aware of the relationship that this course will have with their other classes. All of their activities will involve interdisciplinary studies, covering subjects they have studied or are studying in other departments. Examples include the ability to

use the library and do outside research; the importance of math skills, science principles, grammar, writing skills, speech, typing, artistic skills and the various industrial arts skills. Even the need for and the role of administration are discussed.

After a first day basic problem solving activity students are introduced to two basic fundamentals of the design process: 1) generating alternative solutions, and 2) the formation of a research/documentation report. At strategic points during the first semester, these concepts are expanded as information is pulled from other sources and added to them. In the spring, as students are introduced to control technology, they will have already been exposed to the following topics:

1. Introduction and basic problem solving
2. History and evolution of technology
3. Systems and subsystems
4. The design loop
5. Principles of design
6. Modeling
7. Construction and manufacturing
8. Transportation systems

It is the area of Control Technology and specifically a unit called "Basics of Control" that is the focus of this TD-TEN grant project.

> ***"Control Technology is a term used to describe the interrelationships of many diverse devices brought together within a system for the purpose of having the system function as desired. Control is an aspect of having a device perform a function when a human wants it to do so." (1)***

In order for students to understand how mankind, through the ages, has been able to control his environment, and hence, his lifestyle, by re-directing power and motion, the Magic Box activity was developed. The Magic Box addresses the mechanical, pneumatic, and hydraulic aspects of control technology. Another valuable objective of this learning experience is to develop, using a fun project, the higher level thinking skills beyond knowledge and comprehension. These include...

APPLICATION: The ability to solve problems by applying concepts and appropriate skills.

ANALYSIS: The ability to break down an idea into its component parts and examine them in relationship to the whole.

SYNTHESIS: The ability to solve problems using creative thinking.

EVALUATION: The ability to make judgements and assessments of good or bad, right or wrong, based upon desired results. (2)

These higher level thinking skills addressed by the "Magic Box" activity are the very processes that many business and economic leaders contend are so vital to maintain our position in the world market. Using a five week time span allocated for this activity, students are given the opportunity to develop these skills using the following project description.

PROJECT DESCRIPTION

At the beginning of the control technology unit, students are expected to participate as the class discusses the historical timetable and broad description of the role simple machines, gears, cams, pneumatics, and hydraulics have had during man's existence. The activity that both strengthens these concepts and also supplements their knowledge is then given to the students. The Magic Box assignment involves various inputs, processes, and outputs. Working in teams of two, students now begin the formal problem solving routine.

The activity would be stated differently for each team, but all students would be shown an empty shoe box, inside which they have to build a device that will satisfy the criteria given (Example: on one end of the box, turn a wheel exactly five revolutions. On the other side of the box a vertical rod has to travel up and down three times. Each time, the rod has to travel exactly two inches). The outside of the box must also exemplify the team's creative ability as the overall appearance must relate to the overall theme of the problem as well as being aesthetically pleasing.

As the teams work on each phase of the problem solving process, they will be required to save all of their notes, evidence of research, sketches, experiment results, etc. for their final research/documentation report. This report will be submitted at the conclusion of the activity and is a major part of their grade.

Students will first begin by analyzing the problem given to them. Then, using information presented to them in class, reference books and research materials, in addition to other research conducted on their own, they will put together a design brief. In writing the design brief, the team will make a concise statement of what has to be done and what specifications and limitations must be taken into consideration as they proceed with the problem solving formula.

Before proceeding with the next phase of their problem solution, information they have already assembled is presented to the instructor for evaluation. If satisfactory, the team will then begin the research phase: gathering information on the historical significance of the project, background for their project solution, and also assigned research from a list of related terms supplied to them. This research is gathered from any and all sources, including the library, both in-class and out-of-class reference sources, and even each other. The concept of a massive research team is strongly encouraged, as long as each class member "pulls his/her share of the load."

The next step is for each team to analyze the information they have gathered and develop a minimum of four alternate solutions, each of which is unique from the other. Also at this time, students will implement the systems model and classify each phase of their solution as to input, process, output, feedback, and subsystems. During this phase, students will have access to manufactured parts from component kits (gears, pulleys, syringes, and other materials), catalogs, vendors' literature, and magazines for ideas. They will also determine if components such as cams, base plates, axles, and other parts can be fabricated from raw materials (wood, plastic, metal, etc.) using the facilities they have available.

At this point, each team will develop a detailed design and drawings that can be used to construct the device. This is an area where students can capitalize on their experiences in mechanical drawing and art.

Again, teams are encouraged to interact with one another and also with other sources to accumulate information on science and math principles such as figuring gear ratios, effects of pressure, weight, friction, etc., forces that affect the strength and workability of materials, and any other factors they encounter as they develop their final design.

It is during this aspect of the problem solving experience that direction from the instructor is most important. If enough guidelines, criteria, and information are not given to the students at this point, the construction phase of their design and the final results will fall short of both their and the teacher's expectations. This is the point where the design process will begin to either flow smoothly forward or falter as a result of inadequate background and preparedness. Once substantial information is obtained and a detailed plan is made for construction and is approved by the instructor, fabrication and assembly of a prototype can begin. Student creativity and construction skills are now put to task. With the fabrication of a prototype, or working model, of their selected design, the teams are drilled on safety procedures, rationale for selecting certain materials, using certain tools, and proper use of these tools.

At the completion of this phase the results of the team's research and design skills will be most evident. Not only will they see the visual result of all of their work up to this point, but also of the artistic design and aesthetics as they present their solution as a total design package to the rest of the class. Before the formal presentation, however, the Magic Box is given a final test and a team self evaluation is made. Criteria the team will use for this evaluation includes the five principles of design (function, aesthetics, structure, value, and integrity), and a project evaluation guide. This evaluation also contains a comment section based on four kinds of system outputs:

1. Expected desired
2. Expected undesired
3. Unexpected desired
4. Unexpected undesired (3)

Now nearing the completion point of their learning activity, the students should have a well rounded knowledge of the role these and similar devices have played in the evolution of our society. At this point, the teams are given one more task: to identify applications, careers, and education requirements associated with each aspect of the learning activity. Students are again encouraged to work in larger groups so they may divide the work load and share gathered information whenever possible. Visits to the guidance department, library, employment and professional search agencies, interviews, contacts with local firms and businesses are all valuable sources of information as well as newspapers and magazines. This information is then presented by each group to the class on an informal basis where the instructor and possibly an outside guest can offer additional input so the entire class can get a better understanding of careers and opportunities in various engineering fields, skilled, and semi-skilled trades, in various fields such as food production and processing, space exploration, health and medicine, etc.

The last requirement for the team prior to the presentation to the class is the preparation of a research/documentation report for their Magic Box activity. The format for

this report follows the problem solving design loop. A diagram of the design loop and the evaluation criteria can be found in both the teacher's manual and also the student booklet. It includes:

- Cover page
- Problem statement
- Design brief
- Specifications and limitations
- Research and background information
- Possible solutions
- Defense of chosen solution
- Engineering designs and details
- Construction procedures
- Testing and evaluation
- Redesign and retest
- Final evaluation

NOTES:

(1) The Commission of Technology Education for the State of New Jersey, NEW JERSEY TECHNOLOGY EDUCATION CURRICULUM PROJECT, LEVEL I: INTRODUCTION TO TECHNOLOGY, p. VI.1

(2) Bloom's Taxonomy of Higher Order Thinking Skills

(3) Michael Hacker and Robert Barden, TECHNOLOGY IN YOUR WORLD (Albany, New York, Delmar Publishers Inc , 1987), p. 110

RESEARCH IN SUPPORT OF THE PROJECT ACTIVITY

The definition of technology developed by the Commission on Technology Education for the State of New Jersey and accepted by most educational institutions and organizations in New Jersey is "...the application of knowledge to satisfy human needs and wants and to extend human capabilities." The Principles of Technology course reinforces this definition, and the control technology unit exemplifies it.

Of the units studied, the control technology unit is one of the most enjoyable and rewarding for my students as shown by their enthusiasm and their application of the principles learned to all other other project areas. Within this study unit on control technology, a favorite activity of the students is a 5-week unit on mechanical, pneumatic, and hydraulic transfer of energy and motion called the Magic Box.

Control technology and the Magic Box activity enhance student learning because they embrace the principles of high-order thinking, problem solving, and systems. These principles are just a few that many noted authorities are calling vital to America's future and vital for students if they are to function effectively in their adult lives. Our established goals and objectives are echoed by inventor Stanley Mason (1989) in his thoughts on creativity and problem solving and Professor Lowell Anderson's (1990) discussion on the role of technology education in the development of higher order thinking skills. Dr. Henry Kelly (1990) states that "systems capable of simulating complex work experiences through games and other mechanisms may provide a critical new tool to test the kinds of skills so difficult to measure in standard 'which one is the right answer?' testing." Such statements, which focus on the activity-based problem solving method, support the learning presented in the Magic Box activity.

Classroom reference textbooks such as Discovering Technology: Energy, Power and Transportation (Karwatka & Kozak, 1987) and Technology in Your World (Hacker & Barden, 1987) include extensive material on Control Technology and the many devices used in the processes that contribute to our ability to solve problems in a technological society. Also, as part of a series of reference manuals and activities pertaining to various topics dealing with technology topics such as structures and aeronautics, the British National Centre for School Technology has published complete texts including teachers' guides for modular courses in mechanisms and pneumatics (Page, 1981; Page, 1981). These publications deal solely with the mechanical and pneumatic transfer of energy and power and include student projects that reinforce each unit of instruction.

Hands-on student activities reinforcing control and general technology principles similar to the Magic Box project are published both in textbooks and technology-based educational journals regularly. There are textbook problems involving gear trains and pneumatics (Swernofsky, 1987) and magazine and journal problems dealing with robotics and toy construction that reinforce principles of technology (Hutchinson, P., 1989; Meys, 1988; Todd, 1990). These are examples of real-life applications which make the study of mechanical movements, pneumatics, and hydraulics come alive for students.

The control technology unit at Randolph High School, including the Magic Box activity, was developed using the taxonomy set forth in the course module dealing with control technology in the New Jersey Technology Education Curriculum Project Level 1: Introduction to Technology course. A curriculum project titled Control Technology was published in 1990 under contract from the New Jersey Department of Education, Division of Vocational Education (Hutchinson, J., 1990), and the stated course objectives coincide with the goals and objectives of our unit and the Magic Box activity.

Learning happens through the process of working toward a goal. As students learn of the different kinds of mechanisms and devices that control energy and motion, excitement builds as they are anxious to experiment to see if the theories really work. Problems arise which have many possible answers. Students begin analyzing the possibilities allowing them to develop a device that will allow the smallest person in class to lift a 200 pound football player completely off his feet or realizing that they can make an empty piece of plastic tubing help lift a stack of books off the desk. They are having fun and they are learning and applying critical thinking, teamwork, analysis, problem solving, interdisciplinary subject application, and more. They enjoy building their Magic Box and the learning is obvious through both the process and the result.

RESULTS OF PROFESSIONAL PROGRAM EVALUATION

To ensure that the Magic Box project was meeting the criteria established by the New Jersey Department of Education, Division of Vocational Education, the services of a program evaluation specialist were secured to formally evaluate the learning activity. The following report consists of excerpts from the evaluation report prepared for the Randolph Township Schools and the Division of Vocational Education by Dr. David Weischadle.

(*NOTE:* As part of his credentials, Dr. Weischadle holds a doctorate in curriculum theory and development and a master's degree in curriculum and instruction. He is also a former teacher and school administrator and has participated in activities reviewing innovative projects in school settings for nearly twenty years. Dr. Weischadle has also earned certificates as supervisor, principal, and school superintendent [New Jersey], and has experience in teacher observation, program and lesson analysis, and student behavior. Having over 120 publications, studies, and reports to his credit, a complete resume of Dr. Weischadle's credentials as well as copies of the complete evaluation report can be obtained from either the TD-TEN project director at Randolph High School or the N.J. Department of Education, Division of Vocational Education.)

PROJECT ACTIVITIES

The evaluation plan for the Magic Box activity focused upon a narrative description of the student assignment. In reviewing the description, the consultant identified several process-oriented statements.

The students participating in the Control Technology Project were expected to:

- Participate in class discussions on the historical timetable and broad descriptions of the role of simple machines, gears, cams, pneumatics, and hydraulics.
- Begin formal problem-solving routines.
- (Carry out activities) and save all their notes, evidence of research, sketches and experiment results for their formal research/documentation report.
- Submit a formal report at the conclusion of the activity.
- Carry out the following activities — analyze and investigate problem given to them. develop a design brief, gather information, write a concise statement of specifications and limitations, develop alternatives and choose solution, design and develop a prototype, present final document to instructor.
- Begin construction of the device which meets the specific requirements.
- Test their "Magic Box" to determine if it works.
- Identify applications, career and education requirements associated with each aspect of the learning activity.
- Make formal presentation to the class.

These process statements provided some basis to evaluate other aspects of the project. For example, the statements established parameters to determine how well the project teacher carried out his proposal in terms of developing and using curriculum material that meets the funding criteria.

By providing learning opportunities in the curriculum, it was possible to examine and analyze student learning packets to determine if given the opportunity, the student showed evidence of learning. In addition, the overall curriculum was analyzed for inclusion of the funding criteria and project objectives, the actual presentation of the material to the student in terms of format, clarity, and appropriateness, and strengths and weaknesses of curriculum material itself. A review of the curriculum and lesson plans revealed how well the teacher used the material. These approaches were also supplemented with interviews, both formal and informal in nature.

In addition, the evaluation plan applied the funding criteria and project narrative statements as guidelines in examining teacher-made tests, questionnaires, and surveys as indicators of student learning.

DESIGN

The basis of the summative evaluation was the identification of all student assessment activities conducted by the project teacher. The learning activity documents, questionnaires, checklists, and other material employed by teachers and students were reviewed for appropriateness of concept, content, and usage. In turn, student performance on these instruments were assessed in terms of expectancy levels of this age student and general performance levels of students in this district.

The curriculum materials supporting the "Magic Box" effort was crucial to the project. Hence, the content, methods employed in designing the material, the learning activities, and student performance as evidenced by completed packets formed the basis of the project itself. The documentation of these activities in individualized reports were initially reviewed and appeared to be in a form for analysis. In addition, evidence in the form of curriculum guidelines and teacher lesson plans were reviewed to determine the direction and application of the teaching/learning process.

Much of the evaluation depended on the assessment of students work, curriculum material, and teacher performance. Well established methods of assessment were used in the process. Standardized processes were developed by the evaluator to conduct interviews, review material, observe classes, and correlate activities. Data, in the form of student learning packets and documents, had been collected on an on-going basis. The project teacher developed an array of student assessment instruments and devices. As would be expected, the teacher needed information about how well students were doing in terms of what was taught.

DISCUSSION OF OUTCOMES

The central component of the project was the production of a "Magic Box" which addressed a specific mechanical requirement as indicated in the assignment. Each student, during the 5-week cycle of participation, developed an individualized learning packet. The student generally worked with another student as part of a team. In completing the packet, the student carried out activities which directly addressed the funding criteria. In addition to producing the packet, the student conducted research, analyzed problems,

responded to questionnaires, applied study skills, used simple tools as well as complex hardware and software, and made a formal presentation.

In terms of the funding criteria. the project deals with each of them and provided the following outcome:

CRITERION 1: Developing technological design and problem-solving skills (which include all of the following: analyzing and investigating; framing a design brief; gathering information, generating alternative solutions; choosing a solution; designing and developing; and fabricating a prototype and testing and evaluation)

The essence of the entire project is focused toward this funding criteria. The curriculum, lesson plans, teaching material, and student products reflect in a very substantial fashion that the project teacher offered learning opportunities which initiated the concept early in the school year and continued to reinforce the concept in each term. The prime component of the funded project is the culminating activity, the so-called "magic box." The student documentation, as shown in a direct examination of the documents and in reviewing the teacher evaluation sheets, shows that students are expected to know the components of the approach as described in the project narrative and apply them.

Strong areas were students' ability to state problems, design brief, specification, and limitations, develop alternate solutions, draw and construct details, test and evaluate their alternatives, and then re-design and retest. They were less successful in performing supportive research and defending their chosen solution. For example, almost all the documents had research which consisted simply of defining terms.

A review of their documents also supports these outcomes. Most students seemed to find the drawing and descriptive aspect of the technology process very attractive. The documents contain a number of drawings of both alternative solutions as well as the final solution. In actual class activities, the students appear to use their drawings to guide their thinking and actual building of the devices they design. Clearly, the students depend on their own ability to shape the device which their thinking suggests will solve the problem.

In addition, the document showed wide variance in approaches and responses as well as in neatness and style. The students developed reports or packets reflecting their perception of how they went about solving the problem. In observing these students in a later class, it appeared that each was developing his own approach to dealing with the task. In a very natural sense, each student seemed to be accepting the systematic approach, but adjusting it to his own varying level of intuition and common sense. There was some "leaps" to conclusions that research later would suggest they were right. Notwithstanding the system, such activities must be clearly seen as effective learning processes.

If students were reacting well, it is in part due to the facilitation provided by the teacher during the class time. In the observed session, students were dependent on the teacher being available to assist in considering alternatives and in determining availability of materials. The teacher in this process is an important resource, hence the learning opportunities are enhanced by a knowledgeable teacher able to work in a teaching environment that is highly individualized and somewhat less structured than traditional classes.

CRITERION 2: Reinforcing concepts in science, math, language arts and other subjects

A review of the document produced by the students indicate that technology depends greatly on their ability to apply many principles presented to them in subject areas related to science and mathematics. Most of the drawings in the seven documents required the student to deal with gears and pulleys, important basic components of general physics. In addition, basic mathematic measures, including the application of scale and ratio, were employed by students in appropria fashion. For example, a two-student team produced a device with drawings showing an understanding of scale and ratio, and the required size of the area needed for the machine to operate. In the "Final Evaluation" section of their report, they noted: "Although the mechanism did not work, we still gained much knowledge about simple machines, how they are used, and about the transfer of power and motion." Another used the concept of air pressure to operate a part of the device, but found difficulty in the working of a cam. They concluded that the "angle of the incline is too steep" for it to work properly.

In a subsequent class observation of this class dealing with another problem (i.e., moving a platform along a channel of magnets), students continued to examine and consider important scientific principles to cause motion. Some were considering the use of wind, light batteries, and reverse polarity of magnets. In all cases, students were actively involved in this class of considering alternatives and testing those alterna...s. While two or three had reached a quick decision and were into the building stages, several students and teams were experimenting with size, shape, and composition of the platforms in terms of weights and balance. Clearly important here was the fluid discussion of these scientific principles and related math concerns in student-to student conversations and in student-to-teacher exchanges. It appeared that students were earnestly seeking answers and acquiring insight in these activities, all of which was leading them toward reaching a solution to the problem.

The documents were important ventures in the field of language arts. Not only were students able to discover some answers to problems, they had to explain them in the portfolio they produced. While writing style varied, students responded in key categories related to the systems process. An additional aspect of the reporting process was the video-taping of the final reports, providing an opportunity in verbal skill development as well.

A review of the documents and a class visitation confirmed that students also gained in a number of other areas. For example, the students became very aware of design and their own artistic ability. In one sense, the students simply dealt with the appearance or cosmetic aspect of the device they designed. However, they also realized that the artistic design influenced the operation of the device: e.g., the flow of air over the surface and the effects of drag. In producing the document, they drew plans and illustrations to describe the device and help them produce it.

CRITERION 3: Developing basic skills in the proper use of tools, machines, processes, products, and services of industry and technology

Clearly, the final products developed by the students reflect some very successful outcomes in this particular area, which is best presented by simply listing some observations:

- Students produced some devices which reflected an ability to use tools to finish the product (e.g., file, sander, saw, and glue gun).
- While wood was a prime substance in building the products, students also used plastics, metal, paper, styrofoam, and composite material to build their devices.
- Gluing and fitting were used frequently, rather than nailing or stapling.
- Available material and components (e.g, gears, magnets, and motors) were used if students felt that weight and size requirements could possibly be met.

In the documents supporting the devices, students generally sought to use available material to solve the problems. Frequently, they reshaped the material (e.g., cutting a propeller out of a sheet of tin and twisting the blades to improve the effect of the air), or attempting to make a component out of a lighter material (e.g. cardboard) only to find that the wind bent it. In subsequent observation of the class, it seemed that each student experimented on his own, but was also mindful of what other students were trying also. Indeed, students were learning-by doing, but were also successful in learning from others as well.

There was a good deal of peer-tutelage on a very informal basis. Two students also used their initiative to solve a problem of bonding ("We solved this by combining two types of glue to get a great bond").

Criterion 4: Developing fundamental concepts of how people create and control their environment

Observing students in the classroom and informally discussing their project revealed that students were very aware of how they were in control of the their projects. They were the designer, implementer, and initial evaluator of whether their ideas were reasonable and workable. One student, in particular, noted that he had dealt with other problems given him and he felt confident that he would find a solution to this one as well. Another discussed the problem of weight and how the materials he was currently using were posing problems. Several students dealing with small electric motors were trying to control the size and weight of the power sources, while still considering the possibility of the use of a propeller.

Criterion 5: Developing a team approach to learning

In this relatively small class that had been together for nearly eight months, there seemed to be a rather natural and relaxed ability to work both as individuals and in teams. Indeed, most of the students on the days observed had both formal partners as well as informal partners in the class. There seemed to be a great deal of willingness to share and to observe what others were trying. The openness and camaraderie of the group tended toward a generalized movement toward a solution that was based on input from many members of the class. Adding to this general atmosphere was the instructor who moved about and discussed in an open and friendly manner the criticisms, advise, and suggestions he had about the processes that the students were employing.

In the specific cases where youngsters worked in teams, they were aware of how important it was to divide the work load and share their success. They were intensely aware that their grade was very dependent on working with the other students and providing the needed cooperation to achieve the task. In addition, they were also aware that the work of their team member was important to their own success.

CRITERION 6: Identifying jobs and related education for technology-related careers

The curriculum and teacher interviews indicate that students were instructed in this area. Students generally indicated that they saw important aspects of technology in such careers as computers and computer-related areas of manufacturing where robots are employed. In brief discussions with students, they seemed to be mindful of the work world and the job market. They also were aware of the importance of workable machines and their importance in industry as well as in society.

KEY EVALUATION QUESTIONS

Question 1: ***Did students have the opportunity to learn those general ideas and skills addressed in the funding criteria and project description?***

There is every indication that students had the opportunity to learn the principles and concepts outlined in the funding criteria. They produced material which followed the 9-step format. Having received instruction in the process and in specific areas they are expected to deal with, the students performed as would be expected. Students were actively using tools and applying technology to solving problems given to them by the instructor. The documents they produced followed the systematic approach addressed in the criteria, yet reflected their own style and level of proficiency. In the classroom, they appeared comfortable with the terminology and were actively following the steps.

Question 2: ***When given those opportunities, did student work reflect appropriate learning?***

Based on the documents, the students appeared to be learning the appropriate concepts, ideas, and information for high school students. Working together, either formally or informally, students produced highly individualized documents or portfolios and working models. If one were to use these as criteria in a general sense, the students must be seen as active learners, able to produce working devices based on their thinking and creativity.

Question 3: ***Are the curriculum approaches and materials appropriate for the general ideas and skills presented in funding criteria and project description?***

The activities associated with the project appear to be most appropriate relative to the funding criteria. The activities are driven by the curriculum and the teacher, both of which reflect the technology education model. The 9-step systems approach is a reasonable and sensible concept which students find useful in dealing with the course's task orientation.

Question 4: ***What are the strengths and weaknesses of the current activities?***

Perhaps the most important strength of the project is its basis in the technology education model which fosters the application of a systematic approach to using technology to solve human problems. By using the nine-step approach, students are able to focus on how best to deal with real issues and apply innovative approaches to the resolution of those concerns. Clearly, the approach provides students with a workable model to test ideas and reach conclusions.

A second strength of the project is the emphasis on individualization of instruction and student learning. The student becomes the responsible learner in this approach and is required to present his thinking process from beginning to end. The production of the document necessitates the student to address each area and develop a logical response. Working within a set of parameters, the student is nevertheless able to balance intuition with reasoned analysis, to execute a set of plans he has designed, and share his ideas with others, gaining a better understanding of himself and the value of his thinking.

Another strength is the simplicity of the concepts. Most teachers could well develop an understanding of technology education and use their ingenuity and skill to the use the concept which the project has developed. In addition, the material used in the course are sufficiently developed so that teachers can adopt them in current courses, or plan to develop a technology education course. Furthermore, technology education blends well with the national movement to foster critical thinking in the schools.

Finally, the production of a document or portfolio is very beneficial in that it is something which the student and teacher can identify with personally. In many ways, such documents reveal more than any standardized or teacher-made test can.

A key weakness of the project is the absence of behavior objectives and student performance standards.

Related to this weakness is a clearer picture of how the project promotes science, mathematics, and language arts. It is obvious in a general sense that the project does require some understanding of scientific principles, use of mathematical concepts and techniques, and ability to communicate, but it is unclear in any specific way which skills should be addressed.

Question 5: ***What changes or modifications can be designed and implemented to improve current practices?***

With some discussion and re-writing, the project teacher should be able to develop behaviorally stated objectives and establish some standards in science, mathematics, and language arts which could be addressed and measured. One approach is to require students to address a scientific principle (e.g. air pressure) and a mathematical procedure (e.g., ratio of gears) in discussing the selected solution to the problem.

In developing performance standards in science, mathematics, and language arts, the project teacher could consider working with the teachers in those fields. Specifically, the project teacher could identify teachers interested in reinforcing what they are teaching the technology students in the traditional classes. It would then be possible to build the "magic box" using some of the material being taught in math, adopting some the ideas from science classes, and write the report employing technical writing skills taught in English classes.

Question 6: ***Are activities of the project appropriate for dissemination?***

The fact of the matter is that the project activities are already being disseminated, simply because teachers see the benefits of the idea. The concepts and principles of the Randolph project are generally known and, many teachers, in the natural course of events, acquire the techniques in the forms of handouts and activities and use them as part of their teaching. This sharing of ideas is one of the most powerful dissemination processes

available, and is already in process. Further dissemination of more finished products would certainly encourage other teachers to try this alternative approach from a more traditional, highly teacher-directed instruction.

FINDINGS

Based on the discussion presented above, this evaluator offers the following findings:

1. The students enrolled in the project participated actively in learning activities directly related to the funding criteria upon which the project was supported.
2. The project teacher and Randolph staff carried out the activities for which they were funded in an appropriate and professional fashion.
3. The project will be greatly enhanced by planned purchases of equipment and its use in the classroom.
4. The use of the student documents or portfolios represents a significant and beneficial educational approach to individualized learning.
5. The success of the project is unclear without the presence of some form of student-based performance standards.

RECOMMENDATIONS

1. The State of New Jersey and Randolph Public Schools should continue to invest its financial and human resources in the high school project as a means of providing students with substantial learning opportunities.
2. The project teacher should immediately initiate the development of performance standards so that a more precise idea of student learning in mathematics science, and language arts can be realized.
3. Efforts should be made to work with traditional teachers in the areas of science, mathematics, and English to focus specific concepts and skills which could be reinforced in this technology course.

REFERENCES

Anderson, L. (1989, Sept.- Oct.) Problem Solving in Technology Education. The Technology Teacher, p.

The Commission on Technology Education for the State of New Jersey. (1986). New Jersey Technology Education Curriculum Project, Level I: Introduction to Technology.

Hacker, M. & Barden, R. (1987). Technology in Your World. Albany, N.Y.: Delmar Publishers, Inc.

Hutchinson, P. (1989, Jan.- Feb.). Toying With Technological Concepts. TIES Magazine, p. 5.

Karwatka, D. & Kozak, M. (1987). Discovering Technology: Energy, Power, and Transportation. Harcourt Brace Jovanovich, Inc.

Kelly, H. (1990, August). Technology and the Transformation of American Education. Technological Horizons in Education Journal, p. 63.

Mason, S. (1989, Jan.- Feb.) Fostering Creativity in Students. TIES Magazine, p. 1.

Mason, S. (1989, Jan.- Feb.) How Do I Invent. TIES Magazine, p. 23.

Meys, J. (1988, Feb). Add Robotics - Without Much Expense. The Technology Teacher, p. 25.

Page, R. (1981). Modular Courses in Technology: Mechanisms. Edinburgh, UK: Oliver & Boyd.

Page, R. (1981). Modular Courses in Technology: Pneumatics. Edinburgh, UK: Oliver & Boyd.

Report of the Commission on Technology Education for the State of New Jersey. (1987) Technology Education: Learning How to Learn in a Technological World.

Todd, R. (1990, March - April). Of Roses, Technology, and Students. TIES Magazine, p. 22.

Weischadle, D. (1991). Evaluation Report of Randolph Township High School Control Technology Project.

BASICS OF CONTROL: THE MECHANICAL, HYDRAULIC, AND PNEUMATIC TRANSFER OF POWER AND MOTION

TEACHER'S MANUAL

developed by:

George Collict
Randolph High School
Morris County, New Jersey

February, 1992

This project was conducted pursuant to a contract from the New Jersey State Department of Education, Division of Vocational Education and was 100 percent state funded under the State Income Tax Revenue Account. Monies in this account are appropriated through New Jersey Statutes Annotated, Subtitle 7, State and Federal Aid to Schools, Section 18A:58-34 and 35. The contractors' undertaking of this project were encouraged to express their judgement in professional and technical matters. Points of view or opinions do not, therefore, necessarily represent official funding agency positions or policies.

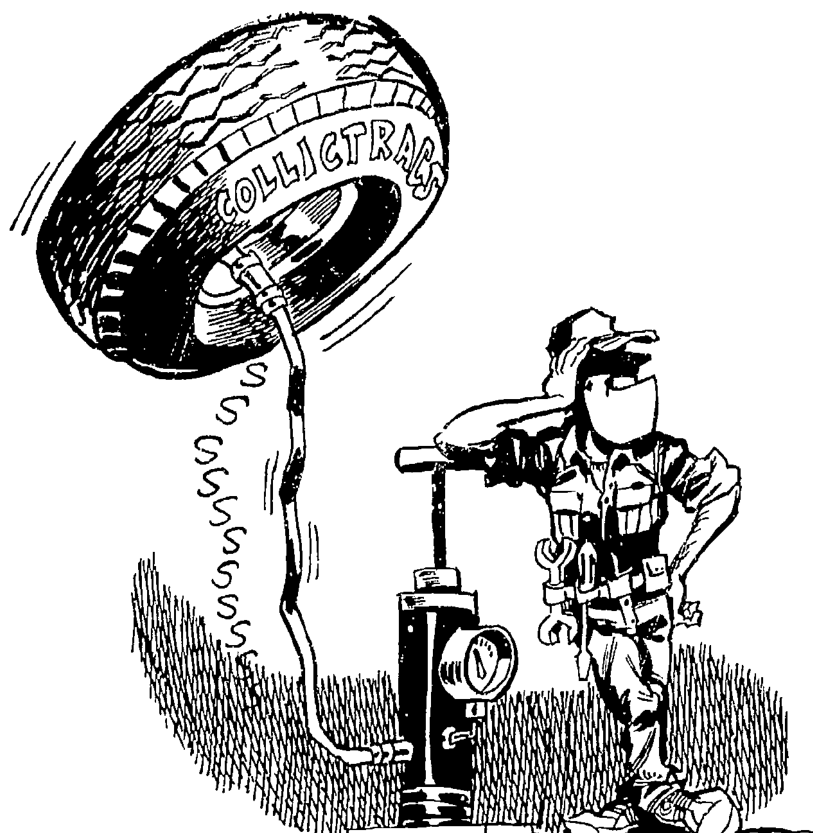
TABLE OF CONTENTS

STATE BOARD OF EDUCATION

ACKNOWLEDGMENTS

Special Note: When making photocopies or other facsimiles of the student or teacher's manual, be sure to include this page of acknowledgments. The illustrations and drawings are copyright protected and should be properly credited.

- Project director: George Collict, Randolph High School, Morris County N.J.
- Project funding: N.J. State Department of Education, Division of Vocational Education.
- Humorous machinery and character illustrations: © Bob Hardin Illustration, Montclair N.J., 1992.
- Layout: donmich Design Studio, Succasunna N.J.
- Fig. 1: © Patricia Hutchinson, Drexel University.
- Fig. 2, 3, 4, 5, 7, 8: © Dr. Ray Page, Project Director, Modular Courses in Technology: Mechanisms (Edinburgh, Oliver and Boyd, Robert Stevenson House, 1985).
- Fig. 6, 10: © Dennis Karwatka and Michael Kozak, Discovering Technology: Energy, Power, and Transportation (Orlando, Florida, Harcourt Brace Jovanovich, 1987).
- Fig. 9, 12: © Thomas French and Charles Vierck, Engineering Drawing (New York, McGraw-Hill Book Co., 1966).
- Fig. 11: © Henry Spencer and John Dygdon, Basic Technical Drawing (New York, The Macmillan Co., 1968).
- Fig. 13: © Oldsmobile Division, General Motors Corp.



GETTING STARTED

INTRODUCTION

Through 25 years of teaching I have followed the "students forget what they hear, remember what they see, and learn what they do" philosophy of instruction. By physically writing their own notes either from information given them in class or by independent research conducted on their own, students are able to keep a log of notes, diagrams, and sketches that can be used to reinforce that learning. What they actually do with the information, however, could be a topic for many educational journals (and comic books!). Those students that keep the information organized and use it in their documentation reports invariably do better than those that don't. But we all know about horses and water, so let's move on.

The unit on mechanical control actually starts with some activities using simple machines. I use a hammer and nail, a block and tackle, a piece of 2 x 8 x 8 ft., a 4" diameter log, and some other assorted goodies. We then experiment with the effects of mechanical advantage.

ACTIVITIES:

1. Have a student try driving a nail by pressing on it with a piece of metal (to protect his/her hand). Now use a forearm with a hammer (lever).
2. Try lifting a very heavy box. Now pull or push it up the 2 x 8 (inclined plane).
3. Try to lift a large classmate. Now use the 2 x 8 and log (lever and fulcrum).
4. Lift another large classmate using the block and tackle (series of pulleys).

OTHER EXAMPLES

Discuss and give examples of (or demonstrate) the other simple machines:

1. Wheel and axle
2. Screw (helix)
3. Wedge

REFERENCE

Michael Hacker and Robert Barden, Technology in Your World, p. 33, and probably many other science and/or technology texts will help you identify the six simple machines.

DISCUSSIONS

After discussing the historical significance and subsequent applications of these machines, the class should be ready to include other devices that provide mechanical advantage...namely gears, cams, pneumatics, and hydraulics.

QUESTION FOR STUDENTS:

How did you get to school today? School bus? Bicycle? Car? Walk?

If anyone rode to school on their bicycle, they took advantage of a wheel and axle, lever, sprockets and chains, and gearing ratios.

- Where are these located?
- The sprocket and chain is a "toothed" version of a pulley and belt system.
  What is its advantage?

If students got here by car or bus, those vehicles use levers, gears, cams, and hydraulics (and sometimes pneumatics) in various systems.

- Identify where these are located and explain their function.

Pneumatics are used on the braking systems of large trucks and city buses. They can be identified by the loud "woosh" sound produced when the brake pedal is released after the brakes are applied.

- How does a pneumatic brake system operate?

ADDITIONAL ACTIVITIES:

1. By using either the chalkboard with a brainstorming session, or individually using a piece of paper, have students list several examples each of the following items that produce mechanical advantage.

Levers	the human body, hammers, pliers, wheelbarrow, pry bars
Pulleys	block and tackle, auto engines, motor drives, machines, early factories
Sprockets	bicycles, motorcycles, chain saws
Gears	transmissions, differentials, steering mechanisms, machines, tools, kitchen appliances
Cams	4 cycle engines, fuel pumps
Hydraulics	brake lines, power steering, automatic transmissions, constuction equipment, robotics, the human circulatory system
Pneumatics	tire pumps, air tools, robotics, air brakes

2. **For the artists:** Sketch a historical use for one or more of the six simple machines, gears, cams, hydraulics, or pneumatics. Sketches can be either factual and serious or fictional and humorous.
3. **For the choppers:** Locate, cut, and arrange on paper several examples of the six simple machines, gears, cams, hydraulics, or pneumatics. Like the previous activity, solutions can reflect the disposition of the creator.

T.L.A.: THE MAGIC BOX

BASICS OF CONTROL: THE MECHANICAL, HYDRAULIC, AND PNEUMATIC TRANSFER OF POWER AND MOTION

UNIT OBJECTIVE:

To reinforce knowledge learned from the previous lesson pertaining to mechanical advantage and to apply the concepts of simple machines, gears, cams, pneumatics, and/or hydraulics to perform specific tasks.

T.L.A. OBJECTIVES:

1. Develop technological design and problem solving skills.
2. Reinforce basic concepts in science, math, language arts, and other subjects.
3. Develop basic skills in the proper use of tools, machines, materials, and processes.
4. Solve problems involving the tools, machines, processes, products, and services of industry and technology.
5. Develop fundamental concepts of how people create and control their environment.
6. Develop a team approach to learning.
7. Identify jobs and related education for technology related careers.

PRIMARY CONCEPTS:

1. Creative thinking
2. Research and information gathering
3. Higher level thinking skills
   - application
   - analysis
   - synthesis
   - evaluation
4. Documentation techniques
5. Sketching and idea presentation
6. Verbal communication skills
7. Selection and evaluation of materials
8. Prototype construction
9. Safe use of tools and equipment
10. Portfolio construction

SUPPLIES NEEDED:

3/16" and/or 1/4" plywood

1/2" clear pine

1/8" balsa strips

1/8" to 1" dia. wood dowels

1/16" to 1/4" dia. CRS or welding filler rod

plastic and/or metal gears (Lego, Pitsco, F-T, etc.)

plastic syringes

1/8" I.D. plastic tubing

assorted brads, wire nails, sheetmetal screws, sheetrock screws

#40 to #240 garnet paper

white glue, jet glue, hot glue sticks

colored markers and/or pencils

TOOLS AND EQUIPMENT NEEDED:

Glue gun

Assorted C-clamps

hack saw, dovetail saw, back saw, portable sabre saw, and/or power bandsaw

hand drill, portable electric drill, and/or drill press

twist drill bits 1/16" to 1/4" dia.

assorted wood and metal files

miscellaneous hand tools: hammers, screwdrivers, pliers, rulers, squares, etc.

FOR THE TEACHER:

The information on the next four pages is part of the student booklet. It is printed here for your convenience. Sections beginning with **FOR THE TEACHER** are for instructor use only and are not part of the student booklet.

T.L.A.: THE MAGIC BOX

BASICS OF CONTROL: THE MECHANICAL, HYDRAULIC, AND PNEUMATIC TRANSFER OF POWER AND MOTION

UNIT OBJECTIVE

To reinforce knowledge learned from the previous lesson pertaining to mechanical advantage and to apply the concepts of simple machines, gears, cams, pneumatics, and/or hydraulics to perform specific tasks.

T.L.A. OBJECTIVES:

1. Develop technological design and problem solving skills.
2. Reinforce basic concepts in science, math, language arts, and other subjects.
3. Develop basic skills in the proper use of tools, machines, materials, and processes.
4. Solve problems involving the tools, machines, processes, products, and services of industry and technology.
5. Develop fundamental concepts of how people create and control their environment.
6. Develop a team approach to learning.
7. Identify jobs and related education for technology related careers.

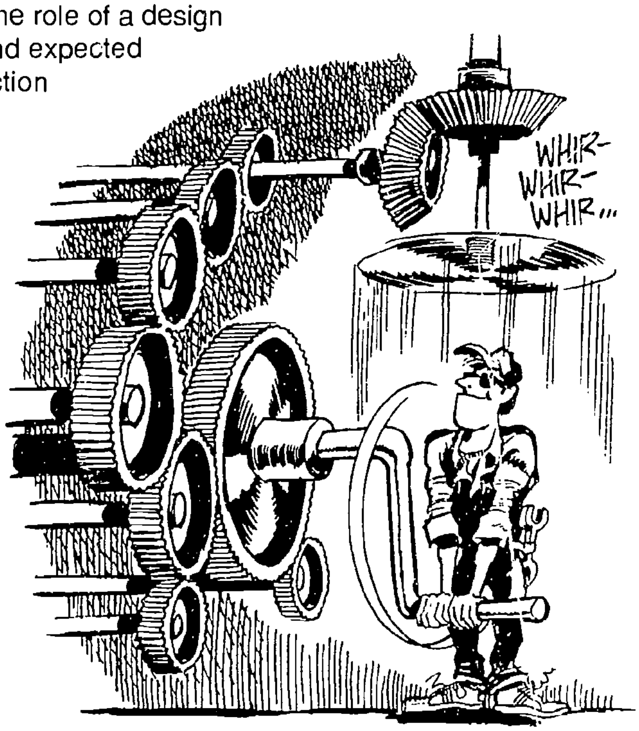
BACKGROUND INFORMATION:

For the past few days your teacher has been helping you understand the importance of mechanical advantage and how it makes work easier for us.

For your next activity you will be assuming the role of a design engineer. You will be assigned to a team and expected to solve a technological design and construction problem.

There are many different problems that your teacher can select from. The one that will be chosen for your team will certainly challange your engineering and design skills.

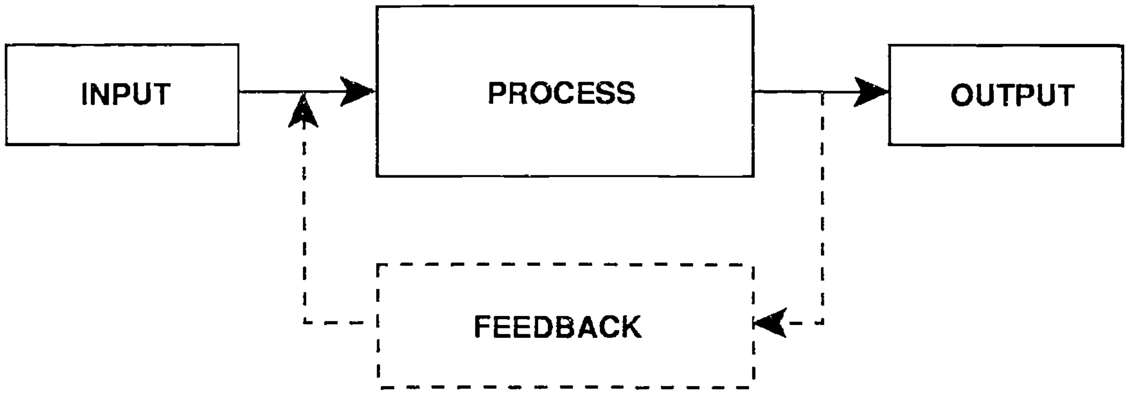
At the end of the activity you should have a better understanding of the job of an engineer and also many other types of work that are associated with engineering and design. Some of these jobs include writing, editing, artwork, drafting, construction, and secretarial support. Whatever your interest, if you like working with new ideas, a career associated with the engineering profession might be worth looking into.



Good luck with your problem.

THE PROBLEM:

Your team will be expected to use one or more devices that produce mechanical advantage to change one type of input to a different type of output (example: change rotary motion into horizontal motion). Whatever problem your teacher selects for you, it will involve the "systems model" of technological design that you have studied in previous units.

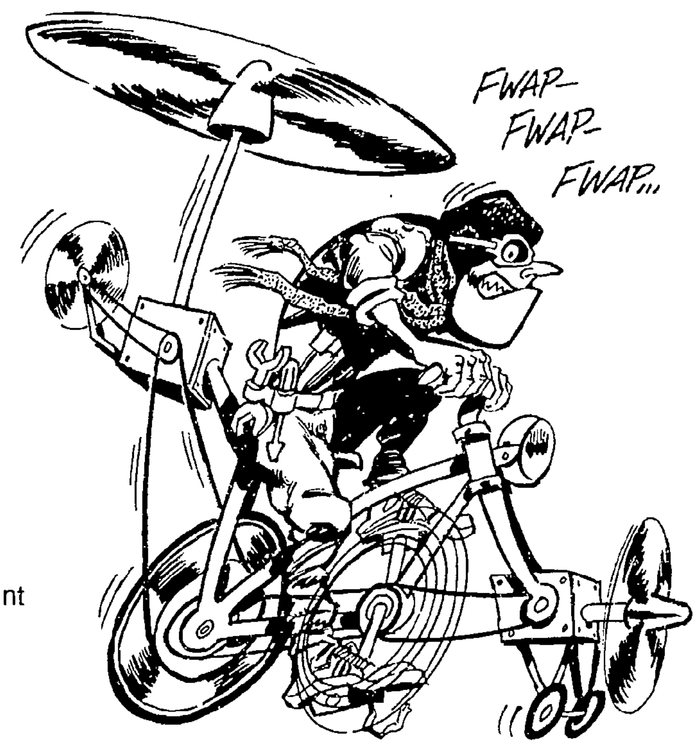


SAMPLE INPUTS:

- Clockwise rotations
- Counterclockwise rotations
- Horizontal movements
- Vertical movements

SAMPLE PROCESSES:

- Levers
- Pulleys
- Sprockets
- Gears
- Cams
- Pneumatics
- Hydraulics



SAMPLE OUTPUTS:

- Clockwise rotations
- Counterclockwise rotations
- Horizontal reciprocal movement
- Vertical reciprocal movement
- Raise and lower a pivot arm
- Open and close grippers
- Ring a bell
- Raise a flag
- Open and/or close a switch

Just as there are many different problems for your team to work on, there can be many ways to solve them. For example, if your team was expected to have an input of one clockwise rotation and an output of two counterclockwise rotations, there are several ways to accomplish this. You could use different arrangements of wheels, pulleys, or gears, or you could use combinations of each. You could search for components that are already made, or you could make your own.

The following design briefs are only samples of what your instructor might assign to your team.

SAMPLE DESIGN BRIEFS:

1. Design and construct a mechanism that will change one clockwise rotation to 4 counter clockwise rotations. Use at least two pulleys.
2. Design and construct a mechanism that will change 5 counterclockwise rotations to one clockwise rotation that is 90 degrees to the input. Use at least two gears.
3. Design and construct a mechanism that will change one clockwise rotation to a 2 inch vertical reciprocal movement. Use at least one cam in the design.
4. Design and construct a mechanism that will change a one inch horizontal reciprocal movement to a two inch vertical reciprocal movement. Use a pneumatic cylinder somewhere in the design.

FOR THE TEACHER: Other sample design briefs are listed below. For gear problems alter the input and output numbers depending on the gear ratios that are available to you or for other reasons as you see fit. You may also want to combine problems (Example: 1 input yielding 2 outputs).

INPUT	PROCESS	OUTPUT	LOCATION
1 cl	pulleys	2 cl	180
1 cl	gears	4 cl	180
4 cl	gears	1 ccl	180
4 cl	pulleys	1 cl	90
2 cl	gears	1 ccl	90
1 cl	cam	2" horiz. rec.	180
2 cl	cam	2" vert. rec.	90
2 cl	cam	2" horiz. rec.	90
2" horiz.	pneu.	90 cl/ccl	90
4 cl/ccl	hyd.	2" vert. rec.	90
4 cl/ccl	any	raise/lower pivot arm	any
2 cl/ccl	any	open/close gripper	any

KEY:

cl = clockwise
ccl = counterclockwise
pneu. = pneumatic
hyd. = hydraulic
horiz. = horizontal
vert. = vertical
rec. = reciprocal
180 = 180 degrees from input (on opposite side of box)
90 = 90 degrees from input (on the next adjacent side)

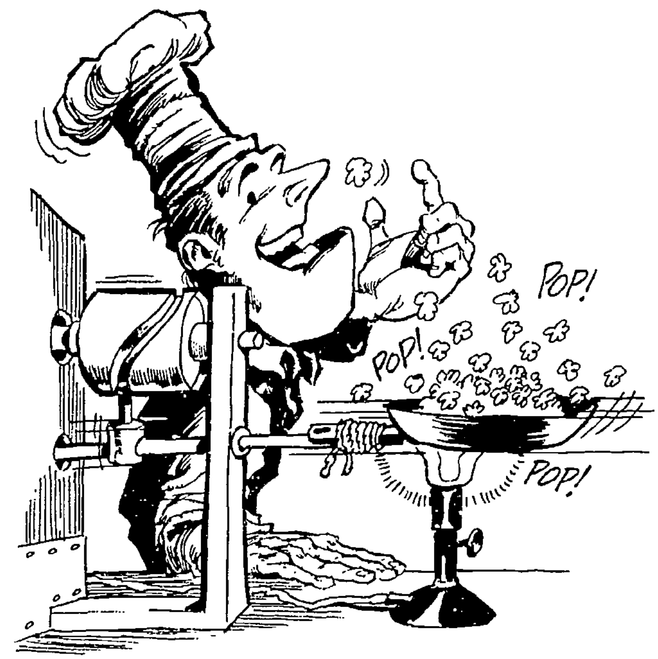
PRINCIPLES OF DESIGN:

FOR THE TEACHER: As part of the problem solving process, student designs should meet certain guidelines that are dictated not only by you, the instructor, but also by logic, common sense, and good taste. These are known as the Principles of Design.

1. Function - Does the device do what it is supposed to do?
2. Structure - Is the device sturdy and reliably put together? Is it overbuilt?
3. Aesthetics - Is the design pleasing to the eye (or other senses as necessary)?
4. Value - Does the design indicate economical use of materials? Are the materials appropriate? Are the fabrication and assembly processes cost effective?
5. Integrity - Does the design reflect good judgement with regard to moral and ethical values? Will it offend anyone?

SPECIFICATIONS AND LIMITATIONS:

The specifications and limitations are the guidelines, or rules, that must be followed. In a real life engineering situation the engineer would meet with the client to establish exactly what must be designed and discuss what specifications are required.



The following list of specifications and limitations should be included as part of your team's final documentation portfolio.

1. Except for the input and output actuators, the entire mechanism must be enclosed in a container approximately the size of a shoe box.
2. The container must allow for visual access to the process mechanism.
3. Both the interior and exterior of the container should conform to the principles of design.
4. Four possible solutions must be developed. Each solution must meet the guidelines set forth by the instructor.
5. Manufactured components such as pulleys, gears, cams, and syringes can be used in the solution. Certain types or sizes of pulleys, cams, etc. that are not readily available can be fabricated from wood, metal, plastic, or other materials.
6. Framework, supports, bushings, etc. can be fabricated from wood, metal, plastic, or other materials. Parts from component kits may be used as long as they are not permanently altered and can be dissassembled for reuse.
7. A team produced portfolio must document the systematic progression of the 9-step problem solving design loop.
8. Each team will make a formal presentation of their problem and solution before the class. During the presentation the team should also review the contents of their portfolio and answer questions as necessary.

(Other specifications and limitations snould be included as necessary.)

THE DESIGN LOOP

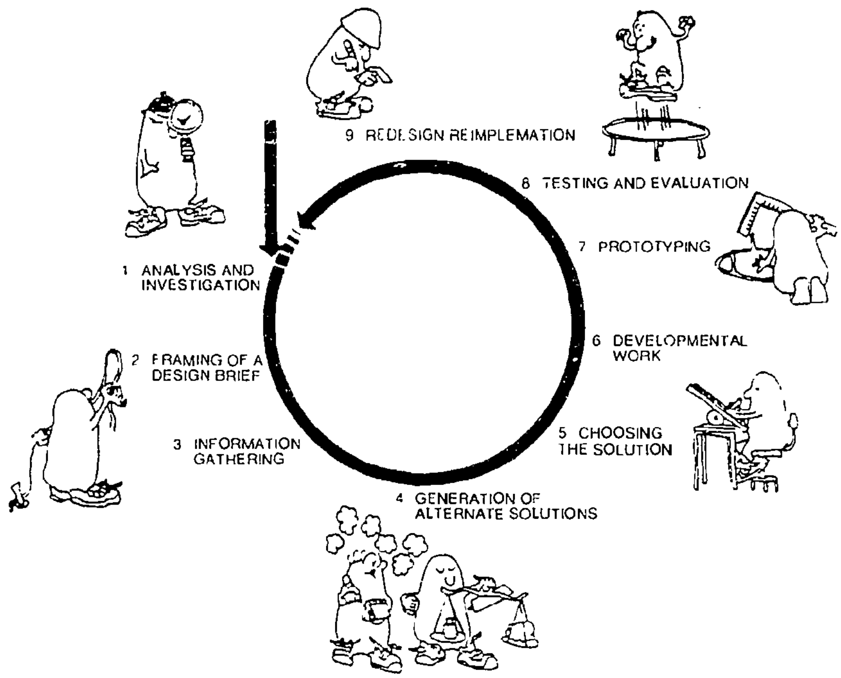


Fig. 1
Designed by Patricia Hutchinson

ADDITIONAL TEACHER GUIDELINES:

In addition to specifications and limitations already given to students (see previous Page), other information that should be reviewed with the design teams is as follows.

- Each design team will consist of two students unless otherwise specified by the instructor.
- Each team will be assigned a design problem by the instructor. The design problem may be from the samples previously given or may be entirely different.
- As part of the documentation process, terminology and material for additional research may be assigned by the instructor to supplement other research done by the design team. Suggested material for research is included at the back of this manual.
- During product testing, each team will be required to document the successes and failures they encountered. These should be listed as...
    - expected desired
    - expected undesired
    - unexpected desired
    - unexpected undesired
- Near the conclusion of the activity, teams should be familiar with each task that was accomplished both in the design and construction of their project and also in the development of their documentation portfolio. Students should now be in a position to identify jobs and careers that are associated with various steps in the design process and they should be encouraged to research them more thoroughly.

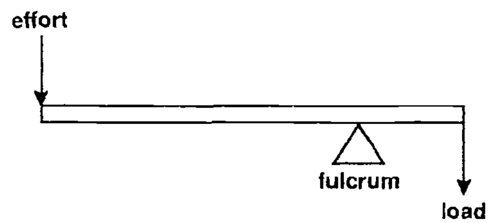
RELATED INFORMATION

FACTS AND FIGURES:

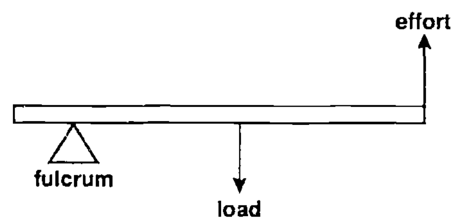
Before having students dive head first into their problem only to have them get stuck in the mud, it is a good idea to present the following facts and formulas so they can calculate necessary information for their designs. This material is also good "common sense" information that can be used for practical purposes outside the classroom.

LEVERS:

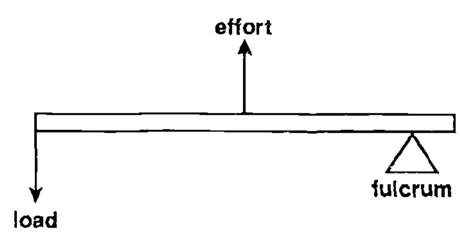
When calculating lever placement, the amount of effort needed to lift an object is directly proportional to the weight of the object and the location of the fulcrum (pivot).



Class 1



Class 2



Class 3

$E = L \times \frac{FL}{FE}$ where...

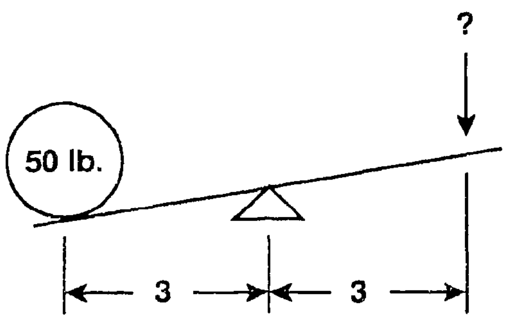
E = effort required

L = load being lifted

FL = distance from fulcrum to load

FE = distance from fulcrum to source of effort

EXAMPLE #1:

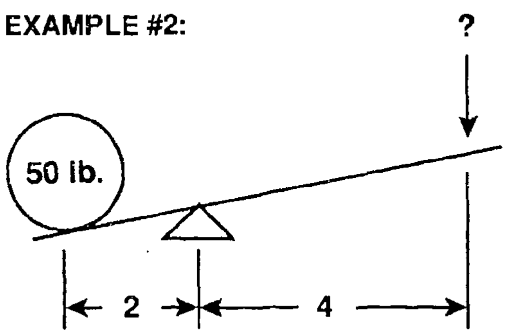


$E = L \times \frac{FL}{FE}$

E = 50 x 3/3

50 lb. of effort is needed to lift the 50 lb. load.

EXAMPLE #2:

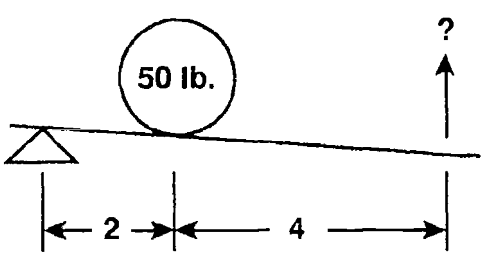


$E = L \times \frac{FL}{FE}$

E = 50 x 2/4

25 lb. of effort is needed to lift the 50 lb. load.

EXAMPLE #3:



$E = L \times \frac{FL}{FE}$

E = 50 x 2/6

16.6 lb. of effort is needed to lift the 50 lb. load.

Note: It is possible for students to experiment with leverage problems using wood and small spring scales.

LIFTING PULLEYS:

When designing a pulley system, the path that the rope must follow is more important than the size or location of the pulleys. It should be remembered, however, that large pulleys are easier to turn than small pulleys (friction!).

$E = \frac{L}{N-1}$ where...

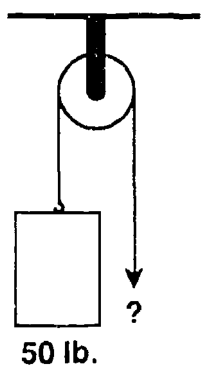
E = effort required

L = load being lifted

N = number of straight sections of rope that are used in the system

Study the following examples very carefully. Note that N minus 1 does not always equal the number of pulleys in the system. Look at example #3. This has 3 pulleys but N minus 1 equals 4.

EXAMPLE #1:



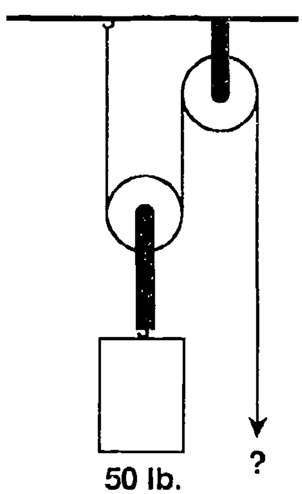
$E = \frac{L}{N-1}$

E = 50/2-1

E = 50/1

In this single pulley arrangement, a 50 lb. effort is needed to lift the 50 lb. load.

EXAMPLE #2:



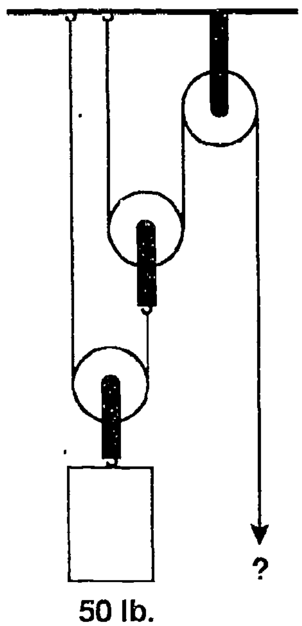
$E = \frac{L}{N-1}$

E = 50/3-1

E = 50/2

In this pulley arrangement, a 25 lb. effort is needed to lift the 50 lb. load.

EXAMPLE #3:



$$E = \frac{L}{N-1}$$

$E = 50/5-1$

$E = 50/4$

In this pulley arrangement, a 12.5 lb. effort is needed to lift the 50 lb. load.

REVOLVING PULLEYS AND SPROCKETS:

These produce mechanical advantage the same way as gears. Refer to the next section on gear ratios for design information.

GEARS:

When designing a gear train, the power (or speed) produced is directly proportional to the ratio of the mating gears.

$R = \frac{D}{P}$ where...

R = ratio

D = size of driven gear

P = size of drive gear (pinion)

EXAMPLE #1:

The ratio of a 10 tooth gear driving a 20 tooth gear is 20/10 or 2/1. The ratio is 2:1. The power is doubled while the speed is halved.

EXAMPLE #2:

The ratio of a 30 tooth gear driving a 10 tooth gear is 10/30 or 1/3. The ratio is 1:3. The power is reduced to one third while the speed is tripled.

EXAMPLE #3:

A 10 tooth gear is driving a 30 tooth gear. On the same shaft as the 30 tooth gear is another 10 tooth gear which is driving a 20 tooth gear. The final ratio is 30/10 x 20/10 which reduces to 6/1. The ratio is 6:1. The power is 6 times greater than original while the speed is only 1/6 as fast.

Note: The above examples (plus others) are fun for the students to build using Lego, F-T, or other component kits.

CAMS:

1. For smooth operation of a radial cam, the total lift should not be more than one third the diameter of the base circle.

   Example #1: A cam with a base circle of 3/4" should not contain more than 1/4" of lift.

   Example #2: If 1" of lift is needed, the base circle of the cam should be at least 3" diameter.
2. The movement of the follower should be carefully planned. A sudden, quick rise will make the follower bind and malfunction. The best way to design a cam is to draw a cam displacement diagram and limit the angle of ascent to 45 degrees. Many technical drafting textbooks show how this is done.

Note: this is an excellent one day lesson and can be used to show students how a typical automobile engine works. A good follow-up assignment would be to ask the difference between an overhead valve engine, an overhead cam engine, and a rotary engine (like the Mazda RX-7).

STUDENT EVALUATION

For the Magic Box T.L.A., 40% of the students' grade is determined by the design project. The remaining 60% is derived by the learning process that is (or should be) evident in the team's documentation portfolio.

A sample student evaluation sheet is included on the next page.

PROJECT EVALUATION SHEET

Name/Team: ______________________________ Period: ________

Study Unit: ______________________________ Date: ________________

DOCUMENTATION PORTFOLIO	Criteria (0-5)	Appearance (0-5)	Factor	Total
Cover page				
Problem statement				
Design brief, specifications				
Research, background info.				
Possible solutions				
Defense of chosen solution				
Engineering designs, details				
Construction procedures				
Testing and evaluation				
Redesign and retest				
Final evaluation				

SUBTOTAL: ____________

DESIGN PROJECT	Criteria (0-5)	Factor	Total
1. Function			
2. Structure			
3. Aesthetics			
4. Value			
5. Integrity			

SUBTOTAL: ____________

RELATED TERMINOLOGY

Mechanical advantage
Class 1 lever
Class 2 lever
Class 3 lever
Fulcrum
Bell crank lever
V-belt
Cog belt
Sprocket
Roller chain
Friction gear
Pinion
Spur gear
Gear ratio
Pitch diameter
Idler gear
Helical gear
Bevel gear
Worm gear
Rack
Reciprocal
Radial cam

Face cam
Toe and wiper cam
Yoke cam
Cylindrical groove cam
Cylindrical end cam
Eccentric
Flat follower
Pointed follower
Roller follower
Pivot follower
Dwell
Cam displacement diagram
Constant velocity cam movement
Parabolic cam movement
Harmonic cam movement
Pneumatic
Hydraulic
"Bleeding" a hydraulic line
Bushing
Bearing
Crankshaft
Connecting rod

FOR FURTHER RESEARCH

- Describe how the sprocket mechanism works in a 10 speed bicycle.
- Describe how the spindle speed of a drill press (or other belt driven machine) is changed using either a single belt system or a double belt system.
- Describe how the gear mechanism works in an electric drill, food mixer, food blender, or other small tool or appliance.
- Describe how a bicycle tire pump works and also a motor driven air compressor.
- Describe how compressed air operated tools work (jackhammer, impact wrench, air hammer, air sander, etc.)
- Describe how a hand operated water pump works and also a hydraulic car jack.
- Describe the operation of a hydraulic brake system and/or a pneumatic brake system (air brakes).
- Describe how the solenoid valves and hydraulic cylinders work to operate a backhoe, bucket loader, or snowplow.
- Describe how a standard transmission works in an automobile or lawn tractor.
- Describe how an automatic transmission works in an automobile.
- Describe how an automobile differential works (both standard and limited slip)
- Describe the relationship of all moving parts in a 4 cycle lawn mower or motorcycle engine (single cylinder).
- Describe the operation of a 2 cycle lawn mower, motorcycle, or chain saw engine.
- Describe the difference between an overhead valve automobile engine and an overhead cam automobile engine.
- Describe the relationship of all moving parts in an automobile engine, including a mechanical fuel pump.

A PAGE OF LEVERS

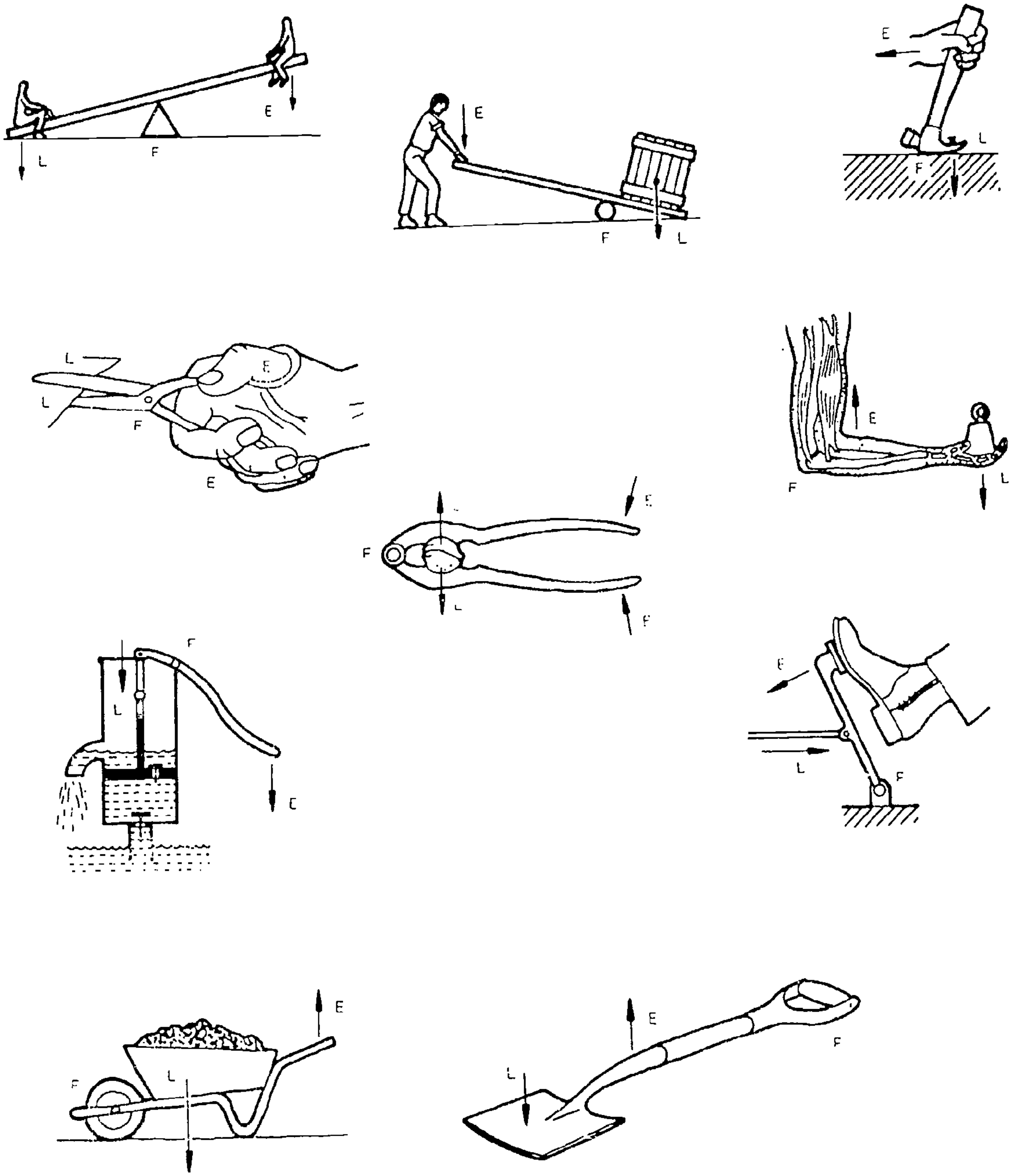


Fig. 2
(entire page)

A PAGE OF LIFTING PULLEYS

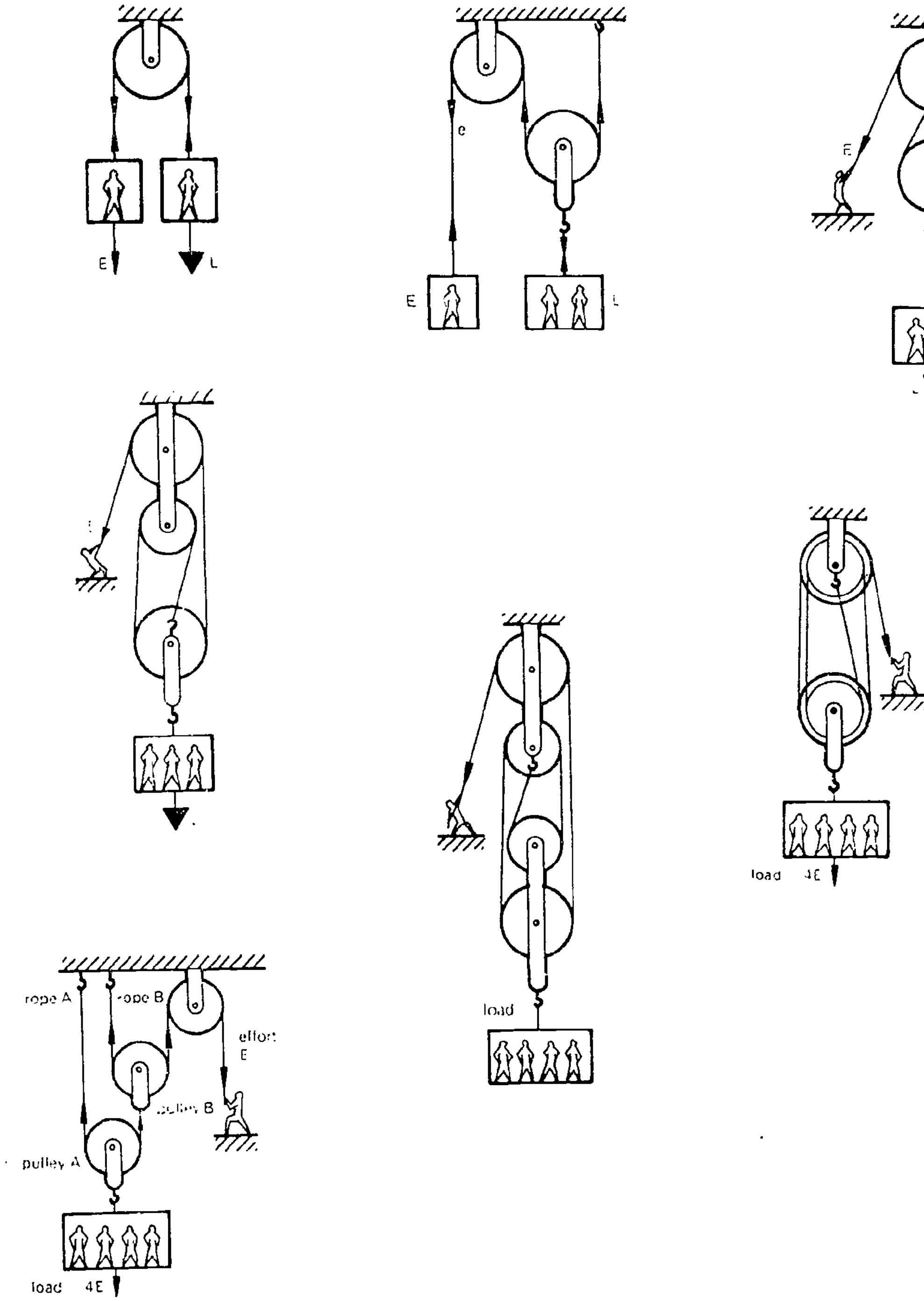


Fig. 3
(entire page)

A PAGE OF REVOLVING PULLEYS AND SPROCKETS

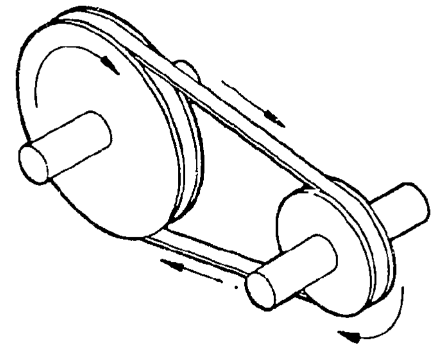


Fig. 4

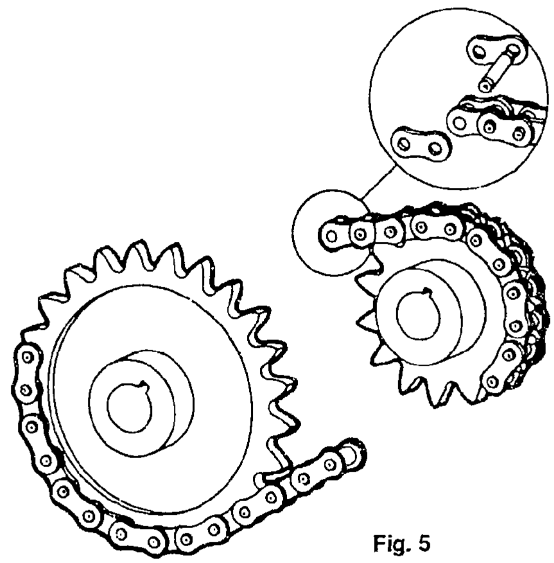


Fig. 5

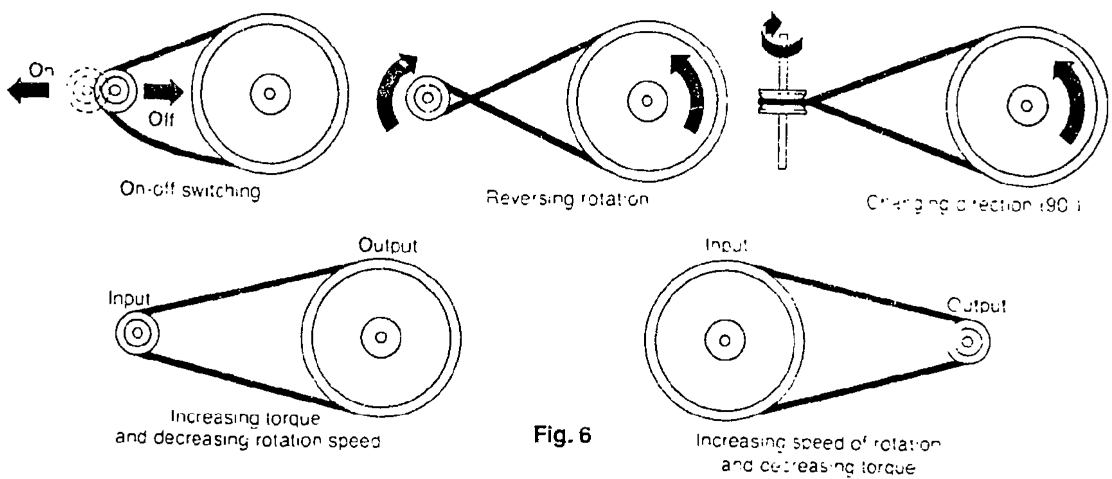


Fig. 6

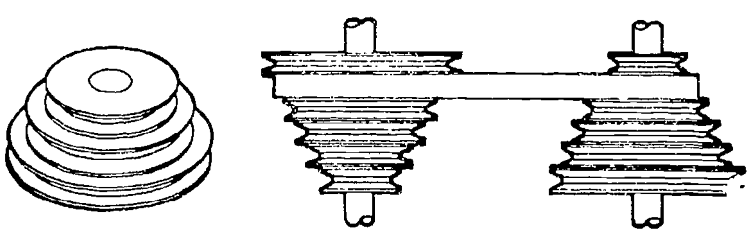


Fig. 7

A PAGE OF GEARS

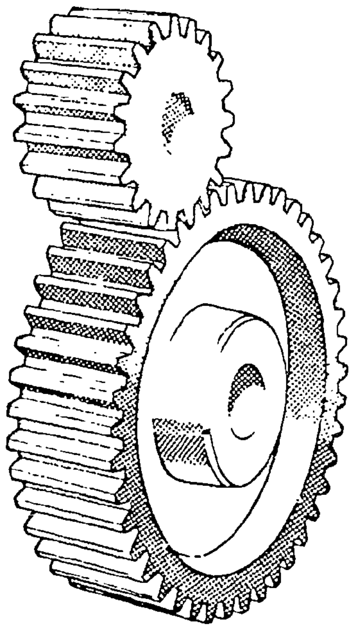


Fig. 8

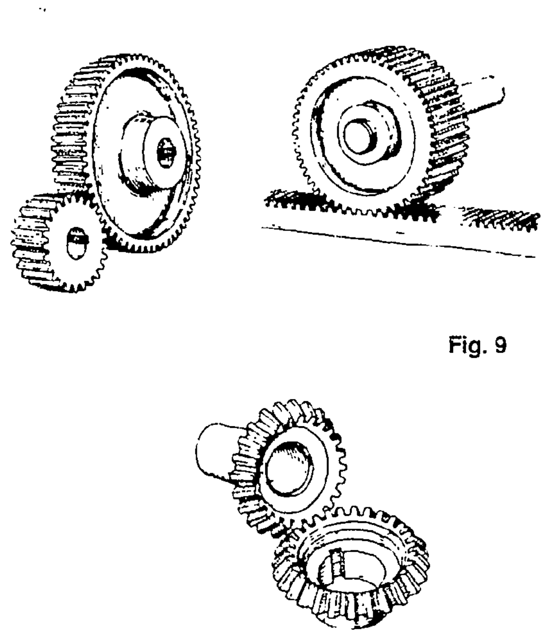


Fig. 9

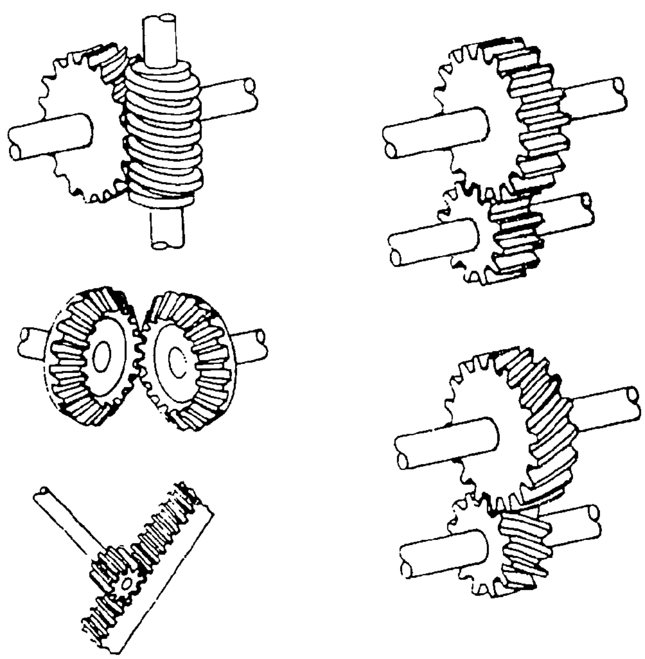


Fig. 10

A PAGE OF CAMS

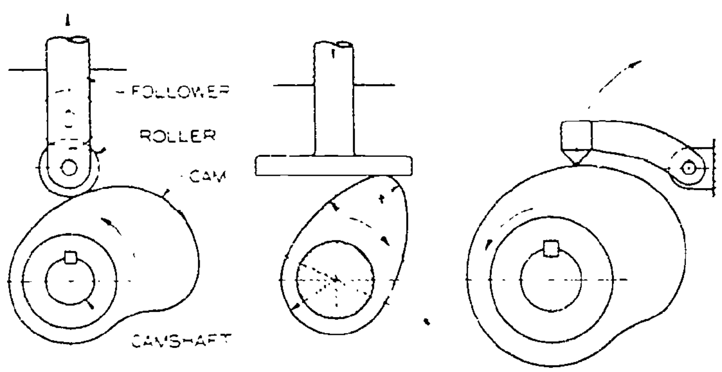


Fig. 11

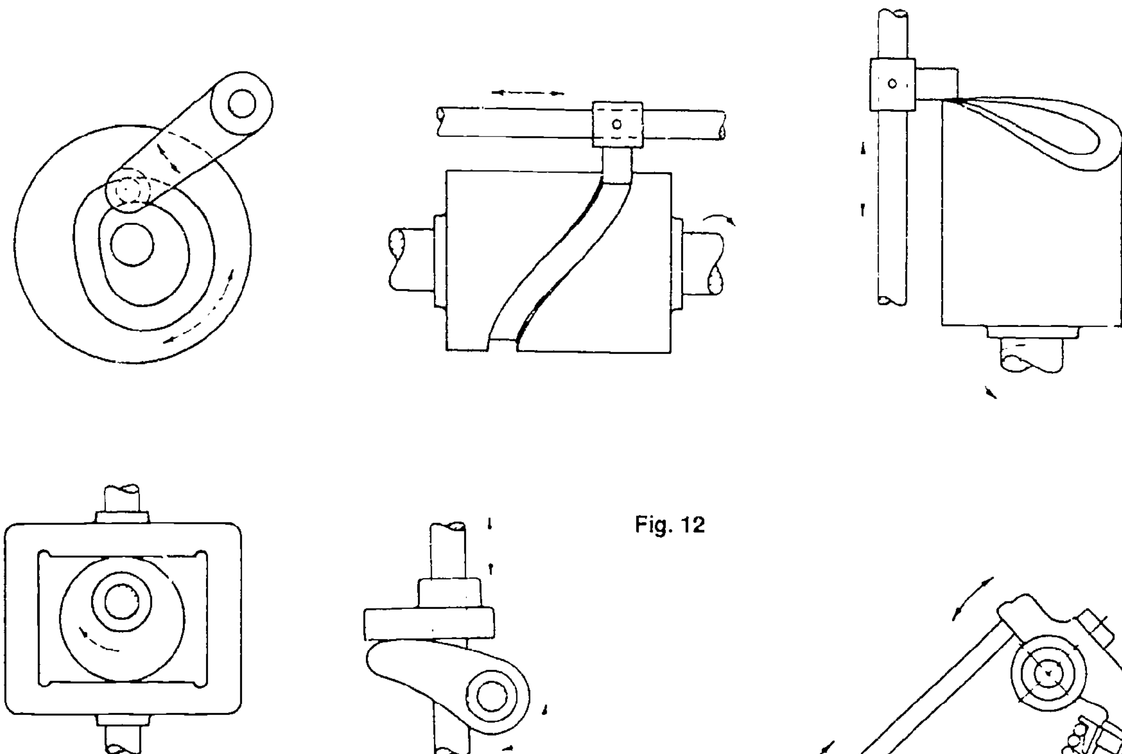


Fig. 12

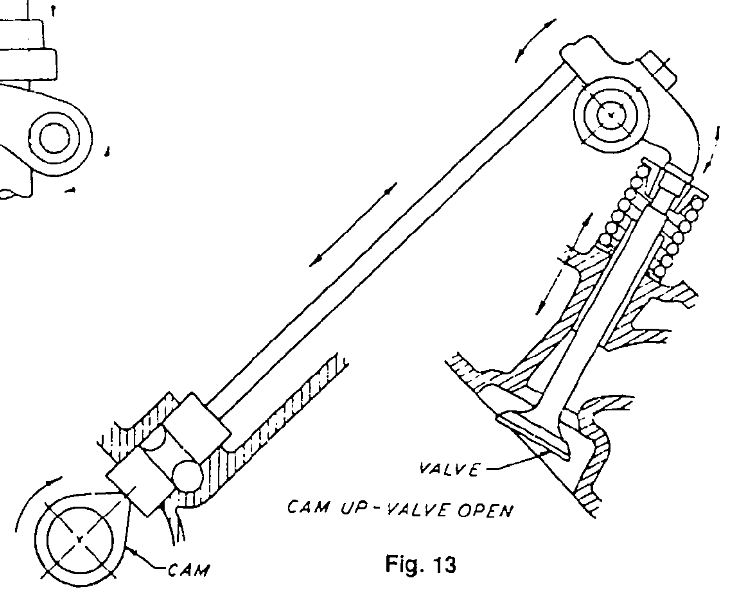


Fig. 13

BASICS OF CONTROL: THE MECHANICAL, HYDRAULIC, AND PNEUMATIC TRANSFER OF POWER AND MOTION

STUDENT MANUAL

developed by:

George Collict
Randolph High School
Morris County, New Jersey

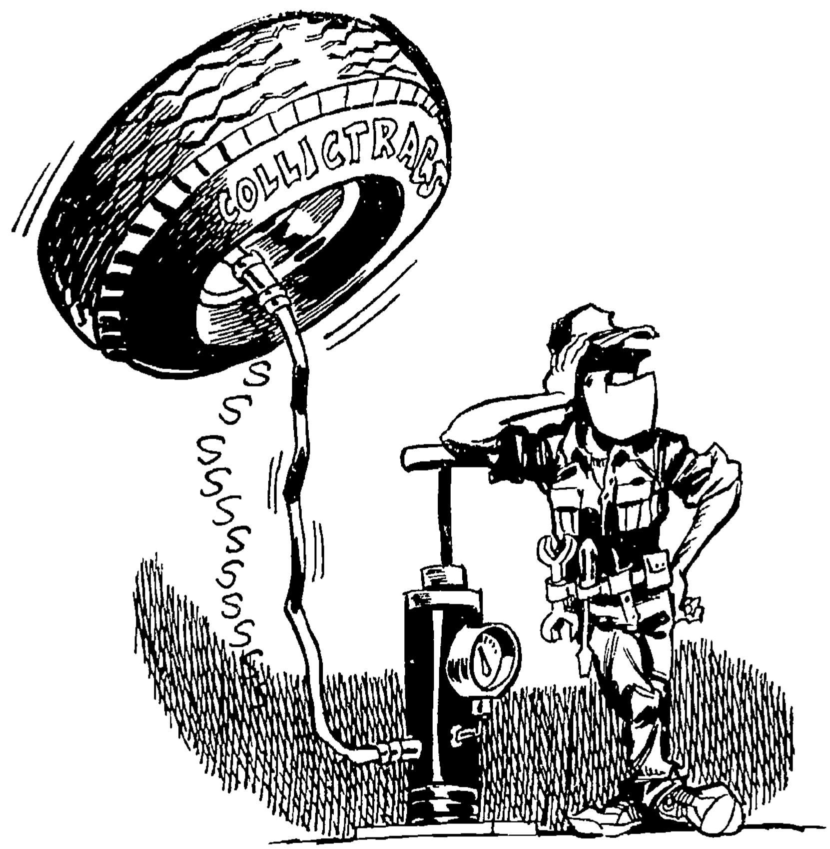
February, 1992

This project was conducted pursuant to a contract from the New Jersey State Department of Education, Division of Vocational Education and was 100 percent state funded under the State Income Tax Revenue Account. Monies in this account are appropriated through New Jersey Statutes Annotated, Subtitle 7, State and Federal Aid to Schools, Section 18A:58-34 and 35. The contractors' undertaking of this project were encouraged to express their judgement in professional and technical matters. Points of view or opinions do not, therefore, necessarily represent official funding agency positions or policies.

ACKNOWLEDGMENTS

Special Note: When making photocopies or other facsimiles of the student or teacher's manual, be sure to include this page of acknowledgments. The illustrations and drawings are copyright protected and should be properly credited.

- Project director: George Collict, Randolph High School, Morris County N.J.
- Project funding: N.J. State Department of Education, Division of Vocational Education.
- Humorous machinery and character illustrations: © Bob Hardin Illustration, Montclair N.J., 1992.
- Layout: donmich Design Studio, Succasunna N.J.
- Fig. 1: © Patricia Hutchinson, Drexel University.
- Fig. 2, 3, 4, 5, 7, 8: © Dr. Ray Page, Project Director, Modular Courses in Technology: Mechanisms (Edinburgh, Oliver and Boyd, Robert Stevenson House, 1985).
- Fig. 6, 10: © Dennis Karwatka and Michael Kozak, Discovering Technology: Energy, Power, and Transportation (Orlando, Florida, Harcourt Brace Jovanovich, 1987).
- Fig. 9, 12: © Thomas French and Charles Vierck, Engineering Drawing (New York, McGraw-Hill Book Co., 1966).
- Fig. 11: © Henry Spencer and John Dygdon, Basic Technical Drawing (New York, The Macmillan Co., 1968).
- Fig. 13: © Oldsmobile Division, General Motors Corp.



T.L.A.: THE MAGIC BOX

BASICS OF CONTROL: THE MECHANICAL, HYDRAULIC, AND PNEUMATIC TRANSFER OF POWER AND MOTION

UNIT OBJECTIVE

To reinforce knowledge learned from the previous lesson pertaining to mechanical advantage and to apply the concepts of simple machines, gears, cams, pneumatics, and/or hydraulics to perform specific tasks.

T.L.A. OBJECTIVES:

1. Develop technological design and problem solving skills.
2. Reinforce basic concepts in science, math, language arts, and other subjects.
3. Develop basic skills in the proper use of tools, machines, materials, and processes.
4. Solve problems involving the tools, machines, processes, products, and services of industry and technology.
5. Develop fundamental concepts of how people create and control their environment.
6. Develop a team approach to learning.
7. Identify jobs and related education for technology related careers.

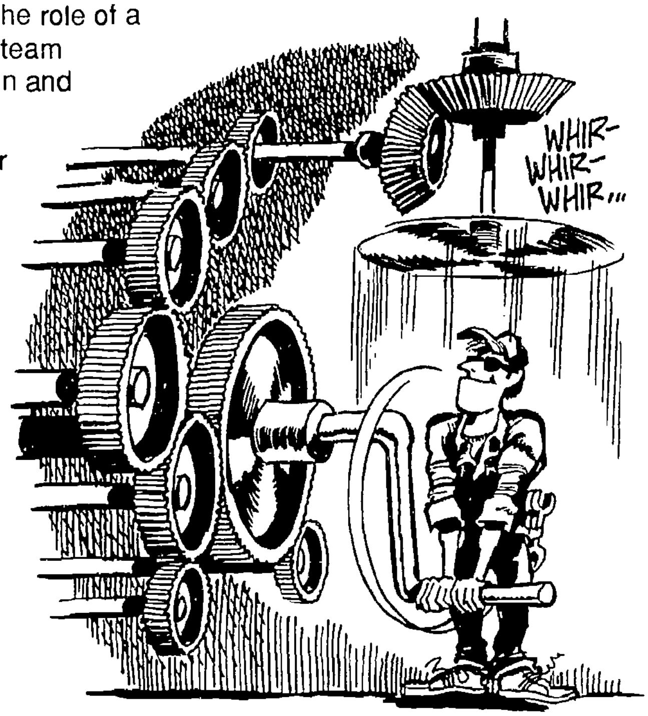
BACKGROUND INFORMATION:

For the past few days your teacher has been helping you understand the importance of mechanical advantage and how it makes work easier for us.

For your next activity you will be assuming the role of a design engineer. You will be assigned to a team and expected to solve a technological design and construction problem.

There are many different problems that your teacher can select from. The one that will be chosen for your team will certainly challange your engineering and design skills.

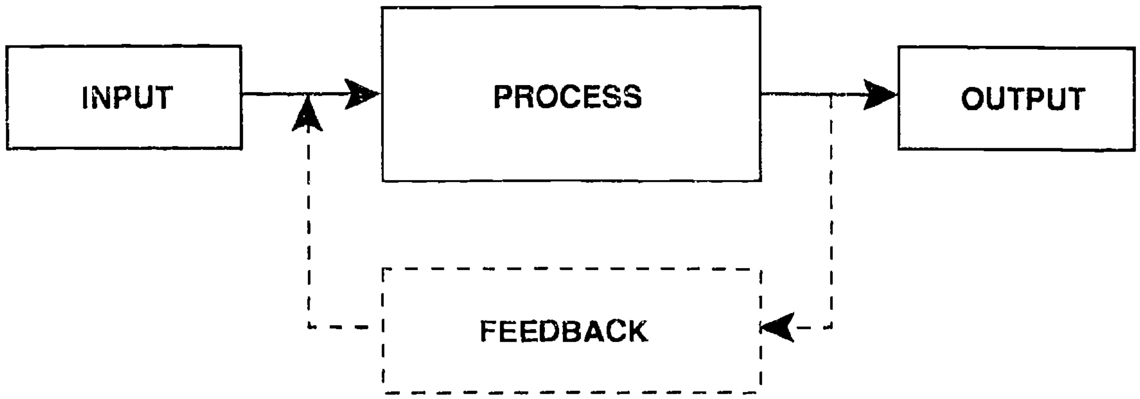
At the end of the activity you should have a better understanding of the job of an engineer and also many other types of work that are associated with engineering and design. Some of these jobs include writing, editing, artwork, drafting, construction, and secretarial support. Whatever your interest, if you like working with new ideas, a career associated with the engineering profession might be worth looking into.



Good luck with your problem.

THE PROBLEM:

Your team will be expected to use one or more devices that produce mechanical advantage to change one type of input to a different type of output (example: change rotary motion into horizontal motion). Whatever problem your teacher selects for you, it will involve the "systems model" of technological design that you have studied in previous units.

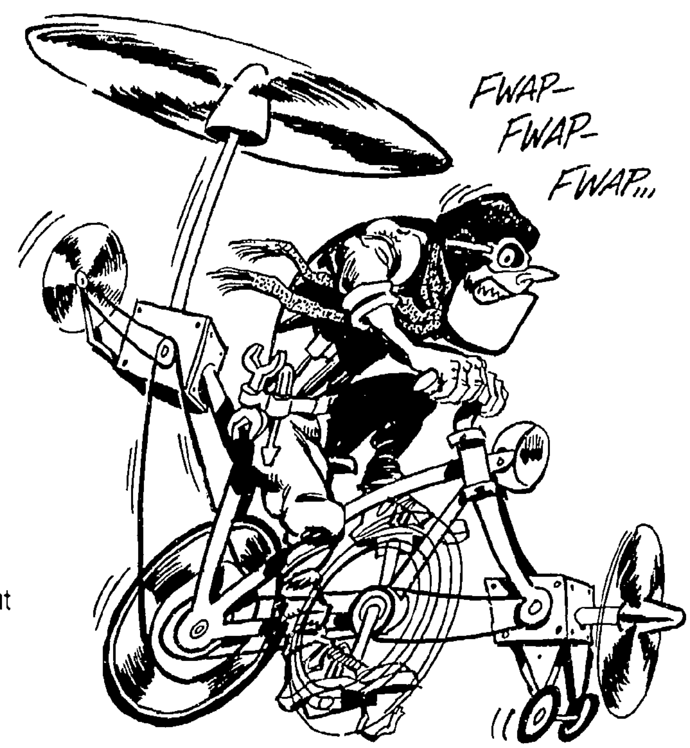


SAMPLE INPUTS:

- Clockwise rotations
- Counterclockwise rotations
- Horizontal movements
- Vertical movements

SAMPLE PROCESSES:

- Levers
- Pulleys
- Sprockets
- Gears
- Cams
- Pneumatics
- Hydraulics



SAMPLE OUTPUTS:

- Clockwise rotations
- Counterclockwise rotations
- Horizontal reciprocal movement
- Vertical reciprocal movement
- Raise and lower a pivot arm
- Open and close grippers
- Ring a bell
- Raise a flag
- Open and/or close a switch

Just as there are many different problems for your team to work on, there can be many ways to solve them. For example, if your team was expected to have an input of one clockwise rotation and an output of two counterclockwise rotations, there are several ways to accomplish this. You could use different arrangements of wheels, pulleys, or gears, or you could use combinations of each. You could search for components that are already made, or you could make your own.

The following design briefs are only samples of what your instructor might assign to your team.

SAMPLE DESIGN BRIEFS:

1. Design and construct a mechanism that will change one clockwise rotation to 4 counter clockwise rotations. Use at least two pulleys.
2. Design and construct a mechanism that will change 5 counterclockwise rotations to one clockwise rotation that is 90 degrees to the input. Use at least two gears.
3. Design and construct a mechanism that will change one clockwise rotation to a 2 inch vertical reciprocal movement. Use at least one cam in the design.
4. Design and construct a mechanism that will change a one inch horizontal reciprocal movement to a two inch vertical reciprocal movement. Use a pneumatic cylinder somewhere in the design.

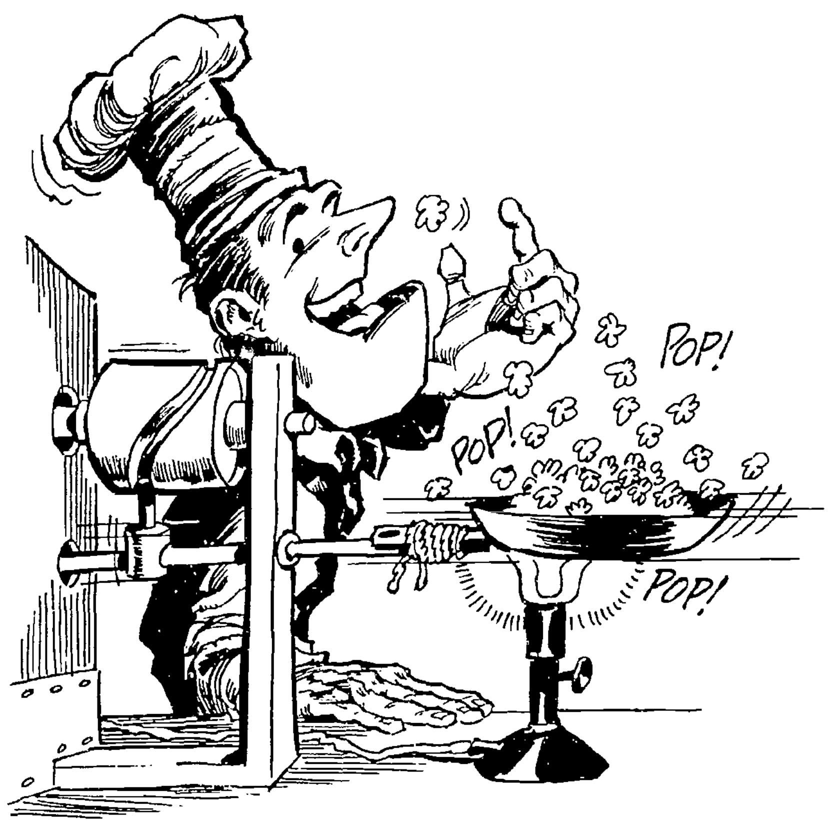
SPECIFICATIONS AND LIMITATIONS:

The specifications and limitations are the guidelines, or rules, that must be followed. In a real life engineering situation the engineer would meet with the client to establish exactly what must be designed and discuss what specifications are required.

The following list of specifications and limitations should be included as part of your team's final documentation portfolio.

1. Except for the input and output actuators, the entire mechanism must be enclosed in a container approximately the size of a shoe box.
2. The container must allow for visual access to the process mechanism.
3. Both the interior and exterior of the container should conform to the principles of design.
4. Four possible solutions must be developed. Each solution must meet the guidelines set forth by the instructor.
5. Manufactured components such as pulleys, gears, cams, and syringes can be used in the solution. Certain types or sizes of pulleys, cams, etc. that are not readily available can be fabricated from wood, metal, plastic, or other materials.
6. Framework, supports, bushings, etc. can be fabricated from wood, metal, plastic, or other materials. Parts from component kits may be used as long as they are not permanently altered and can be dissassembled for reuse.
7. A team produced portfolio must document the systematic progression of the 9-step problem solving design loop.
8. Each team will make a formal presentation of their problem and solution before the class. During the presentation the team should also review the contents of their portfolio and answer questions as necessary.

(Other specifications and limitations should be included as necessary.)



THE DESIGN LOOP

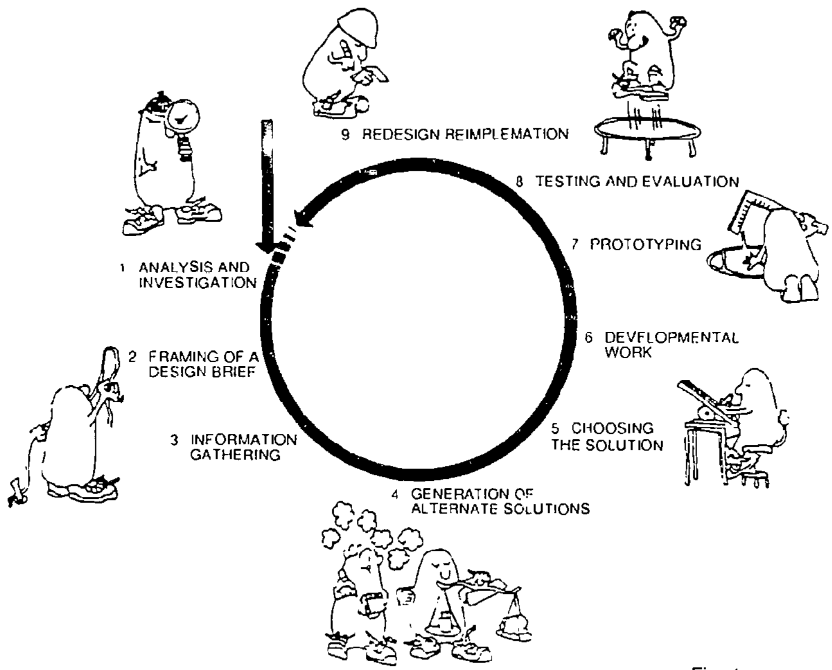
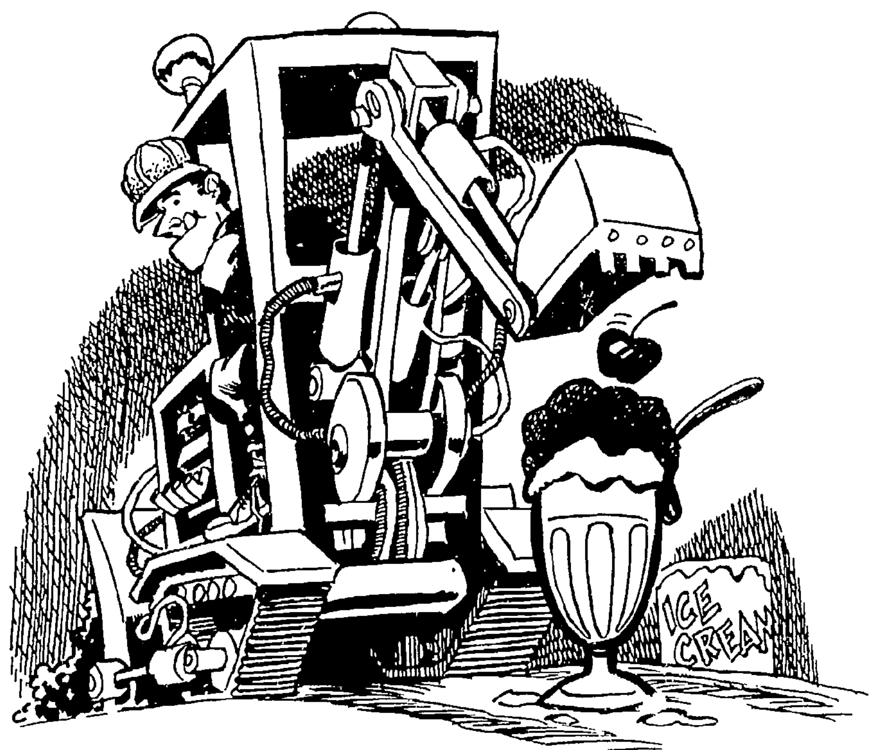


Fig. 1
Designed by Patricia Hutchinson

GRADING:

For the Magic Box T.L.A., 40% of your team's grade is determined by the design project. The remaining 60% is derived by the learning process that is (or should be) evident in your team's documentation portfolio.

A sample evaluation sheet is included on the next page.



PROJECT EVALUATION SHEET

Name/Team: ____________________ ____________________________ Period: ________

Study Unit: _____________________________________ Date: ___________________

DOCUMENTATION PORTFOLIO	Criteria (0-5)	Appearance (0-5)	Factor	Total
Cover page				
Problem statement				
Design brief, specifications				
Research, background info.				
Possible solutions				
Defense of chosen solution				
Engineering designs, details				
Construction procedures				
Testing and evaluation				
Redesign and retest				
Final evaluation				

SUBTOTAL: ____________

DESIGN PROJECT	Criteria (0-5)	Factor	Total
1. Function			
2. Structure			
3. Aesthetics			
4. Value			
5. Integrity			

SUBTOTAL: ____________

RELATED TERMINOLOGY

Mechanical advantage	Face cam
Class 1 lever	Toe and wiper cam
Class 2 lever	Yoke cam
Class 3 lever	Cylindrical groove cam
Fulcrum	Cylindrical end cam
Bell crank lever	Eccentric
V-belt	Flat follower
Cog belt	Pointed follower
Sprocket	Roller follower
Roller chain	Pivot follower
Friction gear	Dwell
Pinion	Cam displacement diagram
Spur gear	Constant velocity cam movement
Gear ratio	Parabolic cam movement
Pitch diameter	Harmonic cam movement
Idler gear	Pneumatic
Helical gear	Hydraulic
Bevel gear	"Bleeding" a hydraulic line
Worm gear	Bushing
Rack	Bearing
Reciprocal	Crankshaft
Radial cam	Connecting rod

FOR FURTHER RESEARCH

- Describe how the sprocket mechanism works in a 10 speed bicycle.
- Describe how the spindle speed of a drill press (or other belt driven machine) is changed using either a single belt system or a double belt system.
- Describe how the gear mechanism works in an electric drill, food mixer, food blender, or other small tool or appliance.
- Describe how a bicycle tire pump works and also a motor driven air compressor.
- Describe how compressed air operated tools work (jackhammer, impact wrench, air hammer, air sander, etc.)
- Describe how a hand operated water pump works and also a hydraulic car jack.
- Describe the operation of a hydraulic brake system and/or a pneumatic brake system (air brakes).
- Describe how the solenoid valves and hydraulic cylinders work to operate a backhoe, bucket loader, or snowplow.
- Describe how a standard transmission works in an automobile or lawn tractor.
- Describe how an automatic transmission works in an automobile.
- Describe how an automobile differential works (both standard and limited slip)
- Describe the relationship of all moving parts in a 4 cycle lawn mower or motorcycle engine (single cylinder).
- Describe the operation of a 2 cycle lawn mower, motorcycle, or chain saw engine.
- Describe the difference between an overhead valve automobile engine and an overhead cam automobile engine.
- Describe the relationship of all moving parts in an automobile engine, including a mechanical fuel pump.

A PAGE OF LEVERS

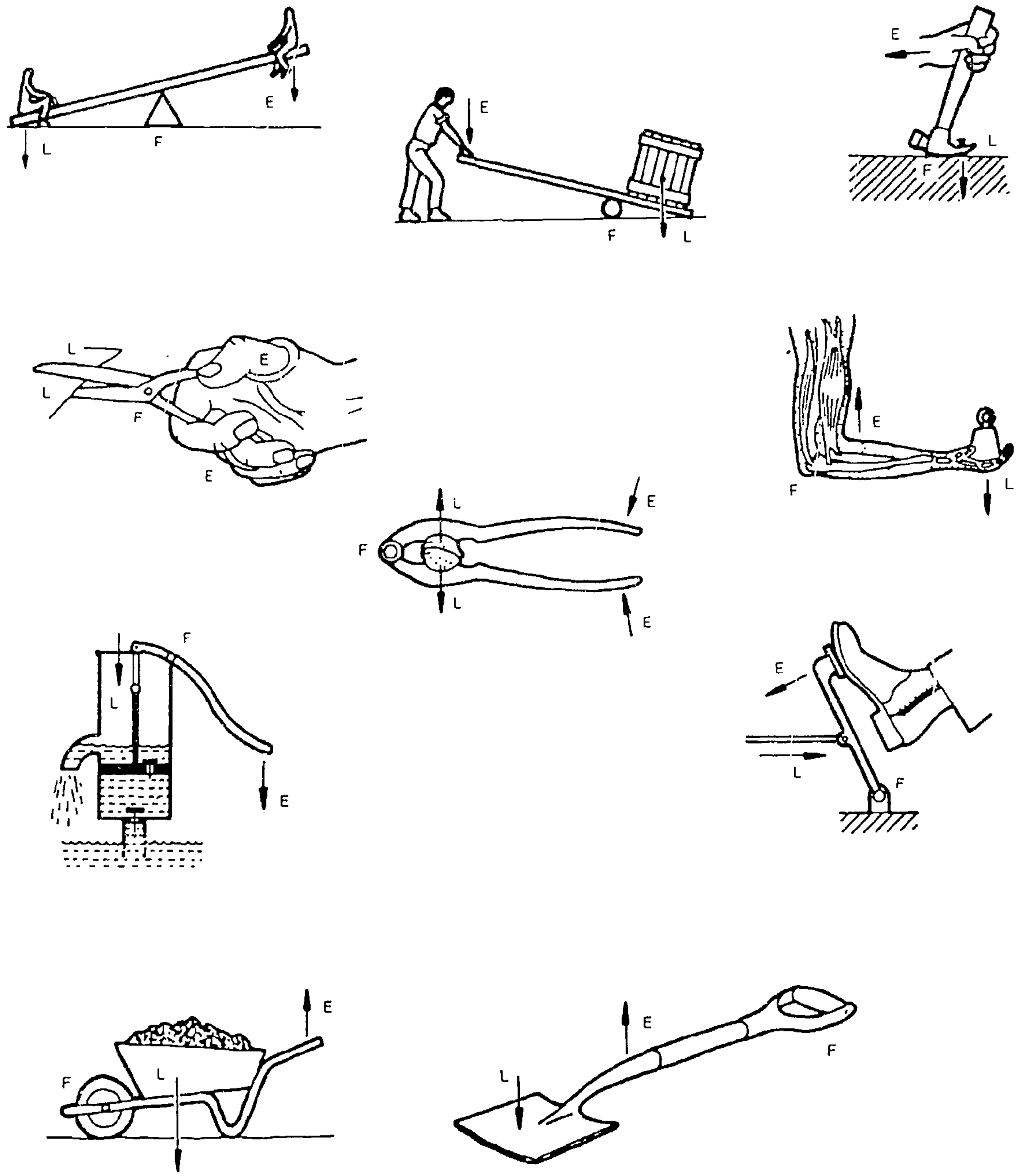
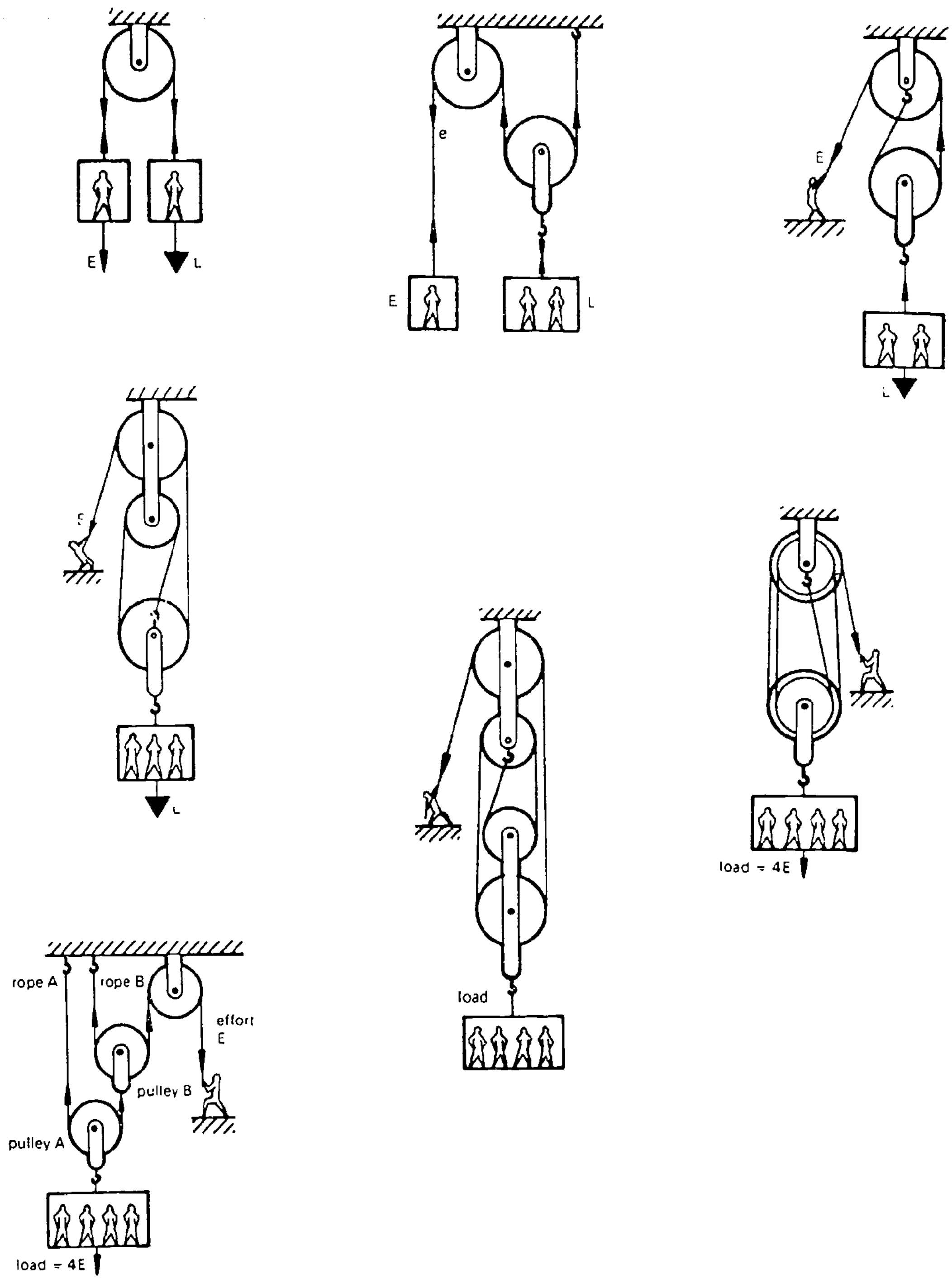


Fig. 2
(entire page)

A PAGE OF LIFTING PULLEYS



61

Fig. 3
(entire page)

A PAGE OF REVOLVING PULLEYS AND SPROCKETS

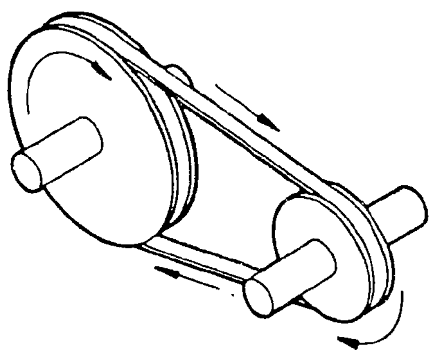


Fig. 4

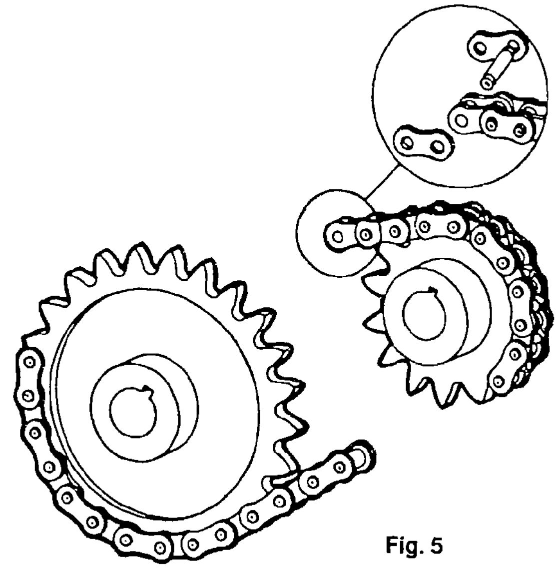


Fig. 5

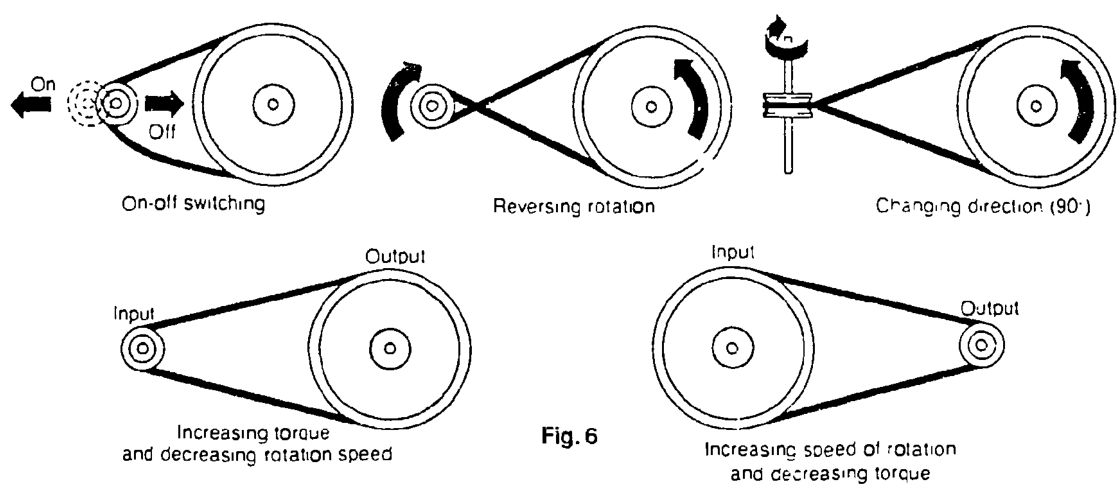


Fig. 6

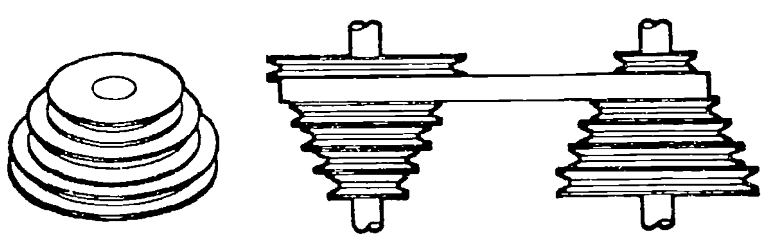


Fig. 7

62

A PAGE OF GEARS

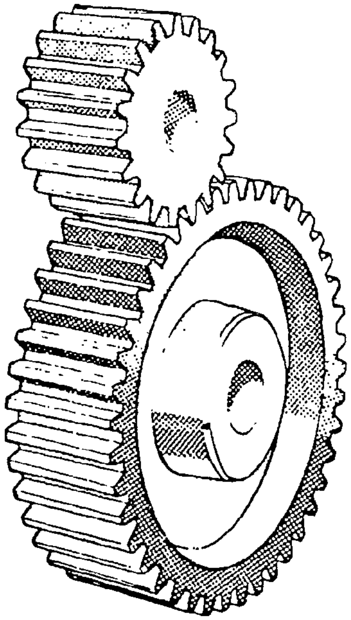


Fig. 8

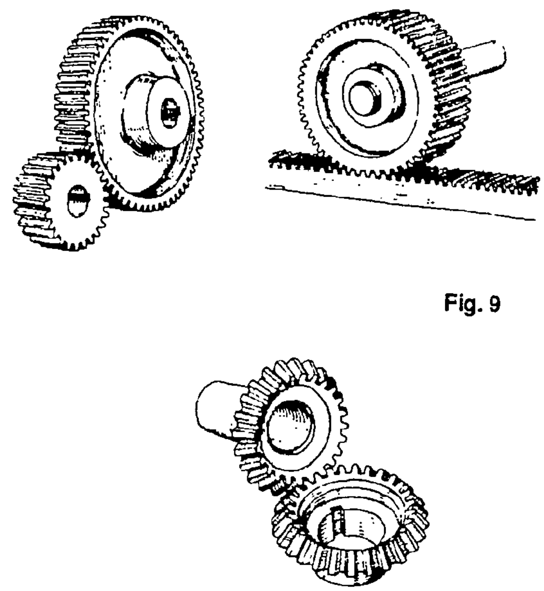


Fig. 9

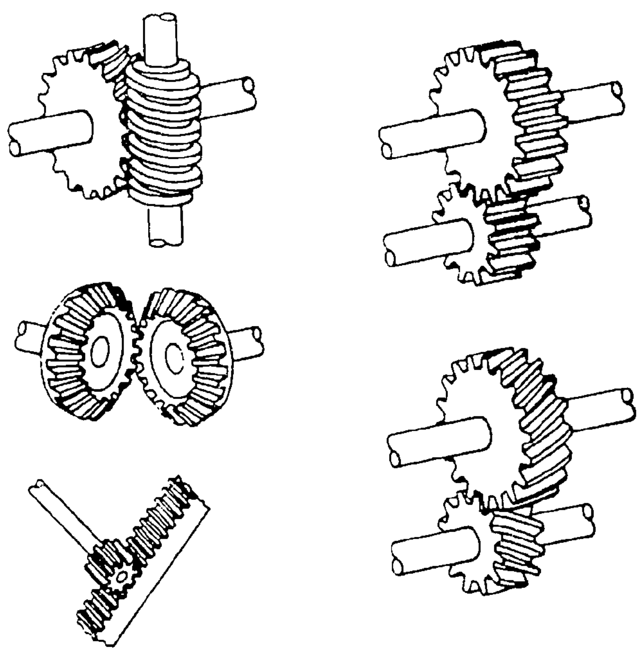


Fig. 10

A PAGE OF CAMS

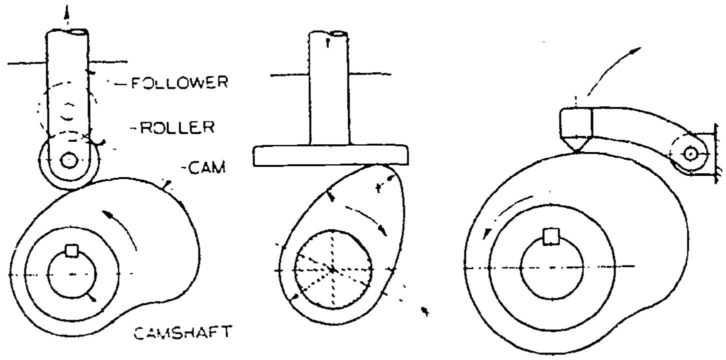


Fig. 11

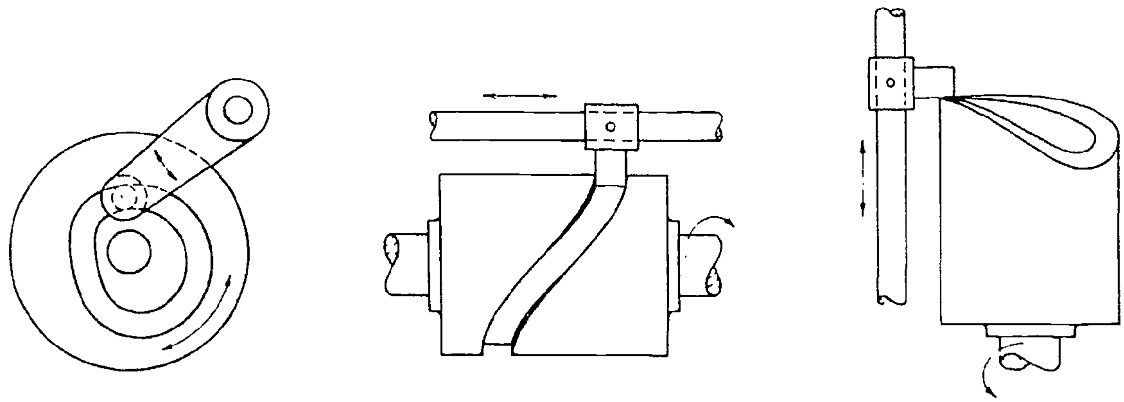
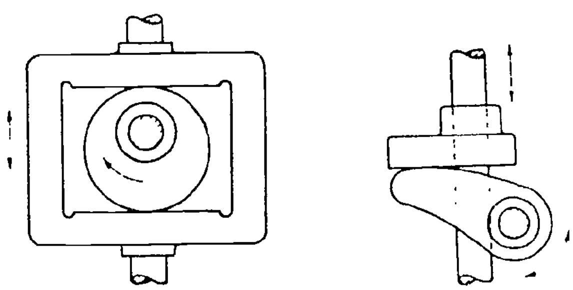


Fig. 12



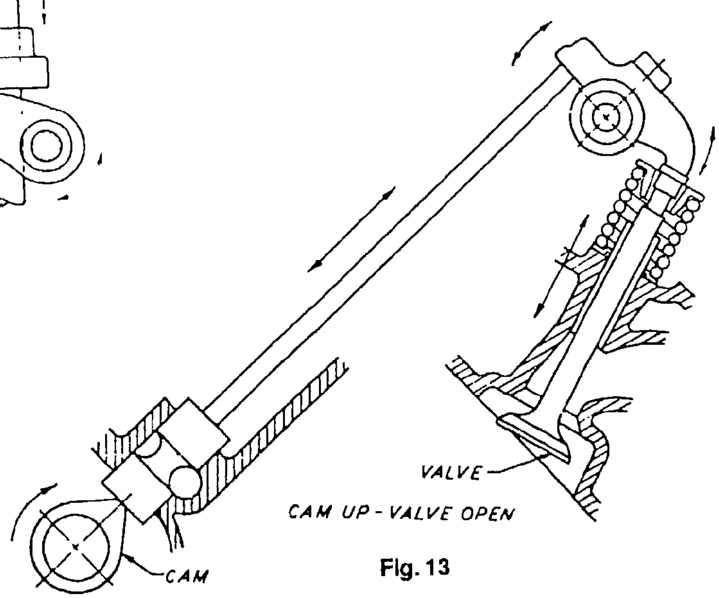


Fig. 13